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Caractérisation des capacités de cognition sociale dans les addictions comportementales via le prisme des troubles liés à la pratique des jeux de hasard et d'argent et des jeux vidéo

Elodie Hurel

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Résumé

Ce travail de thèse a pour objet l'exploration des capacités de cognition sociale (CS) dans les deux addictions comportementales (ACs) actuellement reconnues dans les classifications internationales : le jeu d'argent pathologique (JAP) et le jeu vidéo pathologique (JVP).

La réalisation de deux revues de littérature systématiques a permis de démontrer la rareté des études faisant le lien entre CS et ACs. Cependant, les études trouvées ont suggéré la présence de difficultés pour les patients atteints de ces ACs sur certaines composantes de la CS. Par ailleurs, les éléments cliniques rapportés par ces patients confirmaient la présence de difficultés interpersonnelles.

Ces éléments témoignaient de la nécessité d'explorer le profil de CS des patients avec un diagnostic de JAP ou JVP pour améliorer d'une part la compréhension des processus addictifs, et d'autre part de proposer des soins ciblant les difficultés mises en évidence. Nous avons ainsi mené trois études sur des joueurs de jeux vidéo ou de jeux d'argent, présentant ou non une addiction.

La première étude a démontré des particularités dans le traitement attentionnel des informations sociales chez des joueurs de poker en comparaison de sujets contrôles. La seconde étude a mis en évidence un lien entre les difficultés d'identification des émotions faciales et le JAP, ainsi que des particularités sur le plan de la métacognition sociale en lien avec le JVP. Enfin, les résultats préliminaires de la troisième étude incluant des patients en début de prise en charge pour un JAP ont montré l'importance de prendre en compte les données rapportées par les patients dans le cadre de la CS.

Ces résultats sont discutés au regard des aspects cliniques et scientifiques, et mis en perspective avec de futures recherches possibles.

Mots-clés

Addiction comportementale – cognition sociale – trouble du jeu vidéo – jeu d'argent pathologique – neuropsychologie

Abstract

This thesis focused on social cognition (SC) in the two behavioral addictions (BA) included in international classifications: gaming (GmD) and gambling (GbD) disorders.

Two systematic reviews exposed the scarcity of studies linking SC and BA. Nevertheless, studies included in the reviews suggested the presence of an alteration of some of the SC's components. Additionally, patient-reported outcomes confirmed the presence of interpersonal difficulties.

These elements demonstrated the necessity to explore the SC abilities of patients with Gmd or GbD, in order to improve knowledge on addictive processes and propose alternative treatments focused on these difficulties.

This thesis presented three studies on gamblers or gamers, whether or not they have an addiction.

The first study showed specific allocation of attention toward social information in poker players compared to controls. The second study demonstrated a link between difficulties in identifying facial emotion and GbD and specificities in social metacognition in GmD. Finally, preliminary results of a study regarding GbD patients at the beginning of their treatment showed the importance of taking into account patient-reported outcomes in SC.

Those results were discussed in light of clinical et scientific aspects, and put in perspective with future possible research.

Key-words

Behavioural addictions – social cognition– gaming disorder – gambling disorder – neuropsychology

Table des matières

Résumé	2
Abstract	5
Liste des tableaux	9
Liste des figures	11
PARTIE 1. REPERES CONCEPTUELS	12
1.1. L'addiction comportementale (AC)	12
1.1.1. Histoire du concept	12
1.1.2. Le Jeu d'Argent Pathologique (JAP)	13
1.1.3. Le Jeu Vidéo Pathologique (JVP)	14
1.1.4. Les facteurs de risques de développement et de maintien de l'addiction	15
1.1.5. L'importance de l'approche processuelle dans les addictions	17
1.1.6. Les modèles de compréhension des addictions	18
1.1.7. Une prise en charge possible des processus addictifs : le modèle trans-diagnostique de traitement	22
1.1.8. Aspect social des addictions	24
1.2. La cognition sociale (CS)	25
1.2.1. Origine du concept	25
1.2.2. Les composantes pouvant être incluses dans ce concept	25
1.2.3. Les modèles de compréhension de la CS	25
1.2.4. Prise en charge de la CS	29
Conclusion de la première partie	30
PARTIE 2. ETAT DE L'ART	31
2.1. MANUSCRIT 1 : Revue systématique explorant l'évaluation de la cognition sociale dans le jeu d'argent pathologique (JAP)	32
2.1.1. Résumé en français du manuscrit 1	32
2.1.2. Abstract	33
2.1.3. Introduction	34
2.1.1. Method	35
2.1.2. Results	38
2.1.3. Discussion	39
2.1.4. Conclusion	42

2.2.	MANUSCRIT 2 : Revue systématique explorant l'évaluation de la cognition sociale dans les jeux vidéo (JV)	43
2.2.1.	Résumé en français du manuscrit 2	43
2.2.2.	Abstract	45
2.2.3.	Introduction	46
2.2.4.	Method	49
2.2.5.	Results	51
2.2.6.	Discussion	69
	Conclusion de la deuxième partie	73
	PARTIE 3. EXPERIMENTATIONS	74
3.1.	MANUSCRIT 3 : Evaluation de l'attention aux indices sociaux dans le poker grâce au paradigme d'indication spatiale de Posner	75
3.1.1.	Résumé en français du manuscrit 3	75
3.1.2.	Abstract	76
3.1.3.	Introduction	77
3.1.4.	Methods	78
3.1.5.	Results	83
3.1.6.	Discussion	87
3.1.7.	Conclusions	88
3.1.8.	Perspectives	90
3.2.	MANUSCRIT 4 : Evaluation en ligne des capacités de cognition sociale (CS) chez des joueurs de jeux vidéo (JV) et de jeux de hasard et d'argent (JHA)	91
3.2.1.	Résumé en français du manuscrit 4	91
3.2.2.	Abstract	93
3.2.3.	Introduction	94
3.2.4.	Method	96
3.2.5.	Results	100
3.2.6.	Discussion	107
3.2.7.	Conclusion	112
3.2.8.	Perspectives	113
3.3.	MANUSCRIT 5 : Protocole des études BANCO et BANCO2 et résultats préliminaires de l'évaluation de la cognition sociale chez des patients présentant un diagnostic de jeu d'argent pathologique	114
3.3.1.	Présentation de l'étude BANCO et résumé en français du manuscrit 5	114
3.3.2.	Abstract	116

3.3.3.	Introduction	117
3.3.4.	Method and Analysis	122
3.3.5.	Discussion	130
3.3.6.	Limits	132
3.3.7.	Résultats préliminaires de l'étude BANCO	134
3.3.8.	Discussion et perspectives des résultats préliminaires de l'étude BANCO	140
PARTIE 4. DISCUSSION, LIMITES ET PERSPECTIVES		143
4.1.	Discussion	144
4.1.1.	Résultats issus de ce travail de thèse	144
4.1.2.	Implications cliniques et scientifiques de ces résultats	146
4.2.	Limites	162
4.3.	Perspectives	163
Conclusion		164
Annexes		165
Annexe 1 : Liste des abréviations		166
Annexe 2 : Références		172
Annexe 3 : Données supplémentaires de l'article concernant les analyses de régression de l'étude eSMILE		232
Annexe 4 : Données supplémentaires issues de l'article décrivant les protocoles BANCO et BANCO2		234
S1: Stimulus materials (pictures and words)		235
S2: Apparatus of the study		237
S3: Details on the cognitive tasks		237
Annexe 5 : Données supplémentaires issues des analyses préliminaires de l'étude BANCO ; effet du niveau d'intelligence prémorbide		243

Liste des tableaux

Tableau 1 Critères diagnostiques du DSM-5 pour le JAP	13
Tableau 2 Les 8 sources d'information (8-SIF) - Traduction issue de l'article d'Achim, 2013	26
Tableau 3 Non-exhaustive list of social cognition (SC) components and their possible assessment - Manuscrit 1	36
Tableau 4 Key-words used for the electronic search - Manuscrit 1	37
Tableau 5 Abstracts (n=305) and full-texts (n=17) excluded with reasons - Manuscrit 1	37
Tableau 6 Keywords used in the database search – Manuscrit 2	49
Tableau 7 Reasons for exclusion at each step of the screening – Manuscrit 2	50
Tableau 8 Description of articles found in the systematic search – Manuscrit 2	55
Tableau 9 Sociodemographic, clinical, and gambling characteristics - Manuscrit 3	83
Tableau 10 Final model from the linear mixed model analysis on the benefit index -Manuscrit 3	85
Tableau 11 Final model from the linear mixed model analysis on the cost index- Manuscrit 3	86
Tableau 12 Sociodemographic characteristics and gaming and gambling results – Manuscrit 4	101
Tableau 13 Descriptive statistics of self-reports - Manuscrit 4	102
Tableau 14 Descriptive statistics of cognitive tasks - Manuscrit 4	103
Tableau 15 Descriptive statistics of acceptability questions - Manuscrit 4	101
Tableau 16 Correlation coefficients for self-reports - Manuscrit 4	105
Tableau 17 Correlation coefficients for cognitive tasks - Manuscrit 4	106
Tableau 18 Correlation between metacognitive scores and performance on cognitive tasks - Manuscrit 4	108
Tableau 19 Correlations between metacognitive scores and gaming and gambling characteristics - Manuscrit 4	108
Tableau 20 Measures used for the Diagnosis of BA - Manuscrit 5	123
Tableau 21 Schedule of Enrolments and Assessments Following SPIRIT Guidelines (Chan, Tetzlaff, Altman, et al., 2013; Chan, Tetzlaff, Gøtzsche, et al., 2013) - Manuscrit 5	124
Tableau 22 Measures Used for the Clinical Assessment – Manuscrit 5	125
Tableau 23 Modalities Proposed for Addiction-Related Pictures - Manuscrit 5	126
Tableau 24 Analyses descriptives des participants à l'étude BANCO	134
Tableau 25 Statistiques descriptives et de comparaison de groupe de l'étude BANCO	136

Tableau 26 Coefficients de corrélation entre les tâches cognitives et le score de sévérité de l'addiction	138
Tableau 27 Comparaison entre les groupes et coefficients de corrélation avec le score de sévérité de l'addiction sur les scores normalisés de métacognition	139
Tableau 28 Coefficients de corrélation entre les tâches cognitives et les scores de métacognition	139
Tableau 29 Clinical evaluation at the first visit - Manuscrit 6	155
Tableau 30 Neurocognitive assessment - Manuscrit 6	157
Tableau 31 Clinical evaluation after 6 months of treatment - Manuscrit 6	159
Tableau 32 Regression analysis - Supplementary data - Manuscrit 5	232
Tableau 33 Arousal and valence of picture stimuli - Supplementary data - Manuscrit 5	235
Tableau 34 Arousal and valence of words stimuli - Supplementary data - Manuscrit 5	236
Tableau 35 Données supplémentaires - Analyses préliminaires de l'étude BANCO - Effet du niveau d'intelligence prémorbide	243

Liste des figures

Figure 1 Le modèle processuel de Kinderman issu de Kinderman, 2009	18
Figure 2 Figure traduite et issue de l'article de Brand 2019 révisé.	21
Figure 3 Modèle intégratif 8-SIF bonifié issu d'Achim, 2020	27
Figure 4 Flow diagram of records assessed – Manuscrit 1	39
Figure 5 Flowchart of the systematic review - Manuscrit 2	52
Figure 6 Flow diagram of the Posner cueing task	81
Figure 7 Adjusted predictions and 95% confidence intervals of the benefit index from the final model - Manuscrit 3	86
Figure 8 Adjusted predictions and 95% confidence intervals of the cost index from the final model - Manuscrit 3	86
Figure 9 Timeline of the treatment of the patient - Manuscrit 6	154
Figure 10 Diagram of computerized tasks	242

PARTIE 1. REPERES CONCEPTUELS

1.1. L'addiction comportementale (AC)

1.1.1. Histoire du concept

L'addiction comportementale (AC), aussi appelée dans les premières recherches « addiction non chimique » (Marks, 1990), est un processus dans lequel un comportement spécifique est réalisé pour procurer du plaisir ou soulager un inconfort. Ce processus se caractérise par des échecs répétés de tentative d'arrêt ou de contrôle du comportement et par la persistance du comportement spécifique malgré les conséquences négatives sur les différentes sphères de la vie (Goodman, 1990).

L'évolution des classifications internationales traduit la reconnaissance progressive des ACs comme des entités diagnostiques au même titre que les troubles de l'usage de substances (TUS). Dans un premier temps, le jeu d'argent pathologique (JAP) se trouve défini au sein de la catégorie des « Troubles du contrôle des impulsions non classés ailleurs » dans la quatrième version révisée du Manuel diagnostique et statistique des troubles mentaux (DSM, (American Psychiatric Association, 2000)), et dans la catégorie des « Troubles des habitudes et des impulsions », aux côtés des diagnostics de kleptomanie, pyromanie ou encore de trichotillomanie dans la dixième version de la Classification Internationale des Maladies (CIM, (World Health Organization, 1992)).

Puis, dans les versions suivantes de ces manuels, on assiste à une évolution dans la terminologie utilisée pour qualifier le JAP, dorénavant catégorisé au sein des « Troubles liés à une substance et troubles addictifs » et « troubles dus à des comportements addictifs » dans, respectivement, le DSM5 et la CIM-11 (American Psychiatry Association, 2013; World Health Organization, 2018). Par ailleurs, commence aussi à émerger la reconnaissance de nouvelles ACs : l'addiction aux jeux vidéo (JV) notamment, aussi appelée trouble du jeu vidéo ou jeu vidéo pathologique (JVP), qui apparaît dans le DSM-5 non comme un trouble à part entière mais dans la section des conditions nécessitant plus d'études, et sera finalement inclus définitivement dans la CIM-11 au sein des « troubles dus à des comportements addictifs ».

Enfin, la pratique d'autres comportements, tels que faire des achats (Hussain et al., 2015), avoir des rapports sexuels (Goodman, 2001), manger (Hebebrand et al., 2014) ou encore avoir une activité physique (Chen, 2016), a été citée dans la littérature comme pouvant se transformer en une AC. Cependant, il n'existe pour l'instant pas un niveau de preuve suffisant démontrant des altérations cliniques et neurobiologiques communes aux autres addictions pour pouvoir les inclure dans les classifications internationales (Mann et al., 2017).

1.1.2. Le Jeu d'Argent Pathologique (JAP)

Le JAP est un trouble traduisant des difficultés de contrôle de la pratique des jeux de hasard d'argent (JHA). Le concept de JHA inclut un large spectre de jeux possibles, allant du jeu de hasard pur (loteries, machines à sous, grattages) à des jeux intégrant une part de stratégie (paris sportifs/hippiques ou poker). Les critères du DSM-5 (voir Tableau 1) exposent les différents symptômes éprouvés par ces patients. Parmi les 9 cités, il est nécessaire d'en présenter 4 sur 12 mois, en association avec une souffrance clinique significative, pour que le diagnostic de JAP puisse être posé. Par ailleurs, plus les critères diagnostiques sont nombreux, plus le trouble sera considéré comme sévère.

Tableau 1 Critères diagnostiques du DSM-5 pour le JAP

Critères diagnostiques

- A. Pratique inadaptée, persistante et répétée du jeu d'argent conduisant à une altération du fonctionnement ou une souffrance, cliniquement significative, comme en témoigne, chez le sujet, la présence d'au moins quatre des manifestations suivantes au cours d'une période de 12 mois :
1. Besoin de jouer avec des sommes d'argent croissantes pour atteindre l'état d'excitation désiré.
 2. Agitation ou irritabilité lors des tentatives de réduction ou d'arrêt de la pratique du jeu.
 3. Efforts répétés mais infructueux pour contrôler, réduire ou arrêter la pratique du jeu.
 4. Préoccupation par le jeu (p. ex., préoccupation par la remémoration d'expériences de jeu passées ou par la prévision de tentatives prochaines, ou par les moyens de se procurer de l'argent pour jouer).
 5. Joue souvent lors des sentiments de souffrance/mal-être (p. ex. sentiments d'impuissance, de culpabilité, d'anxiété ou de dépression).
 6. Après avoir perdu de l'argent au jeu, retourne souvent jouer un autre jour pour recouvrer ses pertes (pour « se refaire »).
 7. Ment pour dissimuler l'ampleur réelle de ses habitudes de jeu.
 8. Met en danger ou a perdu une relation affective importante, un emploi ou des possibilités d'étude ou de carrière à cause du jeu.
 9. Compte sur les autres pour obtenir de l'argent et se sortir de situations financières désespérées dues au jeu.
- B. La pratique du jeu d'argent n'est pas mieux expliquée par un épisode maniaque.
-

Dans la CIM-11, le trouble est présent dès lors qu'il y a : (i) perte de contrôle sur la pratique des JHA (en termes de temps, fréquence, mise, etc.), (ii) priorité de la pratique de JHA sur les autres sphères de la vie, (iii) poursuite du comportement malgré l'augmentation des conséquences négatives, avec la présence d'une souffrance clinique (World Health Organization, 2018).

Certains auto-questionnaires permettent d'explorer de manière systématique et standardisée la présence d'un JAP. Une récente revue de littérature a mis en évidence qu'il n'existait que 3 outils dont la concordance avec un entretien clinique semi-structuré permettant d'établir le diagnostic avait été validée (Otto et al., 2020) :

- le South Oaks Gambling Screen (SOGS, (Goodie et al., 2013; Lesieur & Blume, 1987; Weinstock et al., 2007)),
- le Problem Gambling Severity Index (PGSI, (Dellis et al., 2014), aussi appelé Indice Canadien du Jeu Excessif, ICJE (Ferris & Wynne, 2001)),
- le Massachusetts Gambling Screen (MAGS-DSM-IV, (Shaffer et al., 1994; Weinstock et al., 2007)).

1.1.3. Le Jeu Vidéo Pathologique (JVP)

Le JVP est un trouble reflétant une perte de contrôle sur la pratique du JV. Un large spectre de jeux peuvent être intégrés sous le terme de JV, en particulier : les MMORPG (*massively multiplayer online role-playing games* – jeu de rôle en ligne massivement multijoueur), les MOBA (*multiplayer online battle arena* – arène de bataille en ligne multijoueur), les FPS (*first person shooter* – jeu de tir à la première personne), ou encore des jeux sandbox (jeux sans scénario prévu) (Leouzon et al., 2019).

Concernant le JVP, 3 critères sont nécessaires à son diagnostic d'après la CIM-11 : (i) un contrôle altéré sur les JV, (ii) un investissement dans les JV prédominant sur les autres sphères de la vie, et (iii) la poursuite ou l'augmentation du comportement malgré les conséquences néfastes. Pour que le diagnostic de JVP puisse être posé, le trouble doit être d'une sévérité suffisante pour entraîner une altération significative du fonctionnement sur le plan personnel, familial, social, éducatif, professionnel ou dans d'autres domaines importants du fonctionnement et doit être présent pendant au moins 12 mois (World Health Organization, 2018). Concernant la proposition de critères faite dans le DSM-5, ces derniers sont proches de ceux du JAP et il est nécessaire d'en présenter 5 pour que le diagnostic de JVP soit posé : (i) préoccupations au sujet du JV, (ii) symptômes de sevrage, (iii) tolérance, (iv) perte de contrôle sur la pratique de JV, (v) perte d'intérêt sur les autres sphères de la vie quotidienne et de loisir, (vi) continuer le JV malgré les difficultés psychosociales, (vii) mensonge sur le temps passé à jouer, (viii) joue pour éviter un mal-être, (ix) impact important sur les autres sphères de la vie (Leouzon et al., 2019).

Concernant les outils permettant d'évaluer le JVP, une récente revue de littérature a répertorié 32 outils possibles (King et al., 2020). Parmi les plus utilisés sont cités :

- le Young Internet Addiction Test (YIAT, (Young, 1998)),
- le 7-item Game Addiction Scale (GAS7, (Charlton & Danforth, 2007)),
- le nine-item short-form scale to assess Internet Gaming Disorder (IGDS9-SF, (Pontes & Griffiths, 2015)).

1.1.4. Les facteurs de risques de développement et de maintien de l'addiction

Les facteurs de risques pouvant participer au développement et au maintien de l'addiction peuvent être divisés en 3 catégories : les facteurs individuels, les facteurs environnementaux et les facteurs liés à l'objet de l'addiction (Olievenstein, 1984).

Facteurs individuels

De nombreux facteurs de risque individuels ont été mis en évidence dans la littérature concernant les troubles addictifs. Sur le plan sociodémographique, le fait d'être un homme (Severo et al., 2020) et d'être jeune sont des facteurs de risque de développement du JAP (Menchon et al., 2018) et du JVP (Stavropoulos et al., 2019).

Sur le plan clinique, la présence de comorbidités psychiatriques telles que la dépression (Nawi et al., 2021; Severo et al., 2020) ou le stress chronique (MacNicol, 2017) vont favoriser l'émergence d'une addiction. Les antécédents de maltraitance infantile peuvent aussi participer au développement de JAP (A. Roberts et al., 2020) et de JVP (Schneider et al., 2017). Par ailleurs, le fait de se sentir seul est un facteur de risque essentiel au développement du JVP (Li et al., 2021).

Sur le plan de la personnalité, les sujets avec un haut niveau d'impulsivité ou d'alexithymie (trait de personnalité traduisant la difficulté à traiter ses propres émotions (Sifneos et al., 1977)), vont être plus vulnérables au développement d'un TUS (Nawi et al., 2021) ou du JAP (Menchon et al., 2018). L'impulsivité est aussi un facteur de risque de développement du JVP (Rho et al., 2018) mais la direction du lien entre alexithymie et JVP reste à éclaircir (Mahapatra & Sharma, 2018). Les difficultés de régulation émotionnelle peuvent aussi favoriser l'émergence du JVP (Bender et al., 2020).

Sur le plan neurocognitif, les difficultés attentionnelles sont un facteur de risque dans le déclenchement du JVP (Bender et al., 2020). Des altérations cognitives ont été démontrées chez les patients souffrant d'un JAP, marquées par des altérations de la prise de décision et de l'inhibition, par exemple (Challet-Bouju et al., 2017, p.; Hodgins et al., 2011). Cependant, les études menées ne permettent pas de conclure sur le sens du lien de causalité entre déficit cognitif et JAP (Hodgins et al., 2011; Potenza et al., 2019).

Enfin, sur le plan génétique, des études ont établi que certains gènes codant pour les récepteurs et transporteurs de dopamine peuvent favoriser l'apparition d'un TUS (Patriquin et al., 2015). En effet, certaines particularités du système dopaminergique peuvent rendre le cerveau vulnérable à l'addiction. Des études sont nécessaires pour confirmer le lien entre génétique et JAP (Potenza et al., 2019), et entre

génétique et JVP (Paulus et al., 2018). De manière intéressante, il semblerait qu'un variant spécifique du gène FOXP2 soit un facteur de risque génétique commun aux ACs et TUS (Vereczkei et al., 2022).

Facteurs environnementaux

Sur le plan environnemental, le fait de manquer de supervision par les parents ou d'avoir des parents consommateurs sont des facteurs de risque dans le déclenchement des TUS. La sphère parentale peut aussi jouer un rôle protecteur lorsque par exemple les pères ont été sensibilisés aux problématiques addictives (Nawi et al., 2021). Pour le JVP, la qualité des rapports familiaux peut négativement impacter la sévérité de l'addiction (Schneider et al., 2017) et aussi en favoriser le déclenchement (Bender et al., 2020; Gentile et al., 2011). Pour le JAP, le fait que des personnes de l'environnement familial jouent est un facteur de risque de développement de l'addiction (Hodgins et al., 2012).

Facteurs liés à l'objet de l'addiction

Enfin, l'objet de l'addiction, que ce soit une substance ou un comportement, peut avoir un potentiel addictif différent en fonction de ses caractéristiques. Pour les substances, elles peuvent être classées en fonction de leur potentiel de pharmacodépendance, mis en évidence grâce à des études sur les modèles animaux ou humains (Food and Drug Administration, 2017). Il est par exemple possible de mener des études de pharmacocinétique sur l'impact de la substance sur le système nerveux central. En effet, plus une substance va rapidement atteindre le cerveau, plus cela augmentera la motivation à reprendre la substance (Allain et al., 2015).

Concernant le JAP, les caractéristiques structurelles des jeux vont aussi faire varier leur potentiel addictif en satisfaisant ou non les besoins des joueurs, et donc en favorisant ou non, le développement de l'addiction (Parke & Griffiths, 2007). Par exemple, plus le délai entre la mise et le résultat est faible, plus le potentiel addictif est élevé. Cela signifie que sur cet aspect les jeux de grattage, dont le résultat est immédiatement connu, peuvent avoir un potentiel addictif plus important que les jeux de tirage, dont le résultat est connu en différé, comme l'Euromillion. La présence de quasi-gains (*near misses* – principalement sur les machines à sous, lorsque deux symboles apparaissent sur une ligne de gain, et que le troisième symbole identique gagnant est juste en dehors de la ligne) peuvent aussi favoriser l'apparition d'un comportement excessif. Les caractéristiques des gains (fréquence et niveau) ou encore de la fréquence de mise (possibilité de rejouer immédiatement ou non) peuvent aussi faire varier le potentiel addictif (Parke & Griffiths, 2007). Concernant l'aspect disponibilité du jeu, le fait de pouvoir pratiquer en ligne est également un facteur important qui fait augmenter son potentiel additif. En effet, ces JHA sont de ce fait plus anonymes, accessibles et stimulants sur le plan sensoriel, ce qui favorise l'immersion mais aussi la désinhibition (M. Griffiths, 2003). Pour le JVP, certaines caractéristiques des JV peuvent aussi augmenter le potentiel addictif d'un jeu : le fait qu'il n'y ait pas de fin définie au jeu, l'importance de la reconnaissance sociale et de la coopération, la compétition, mais aussi le renforcement continu lié au jeu (Thorens & Zullino, 2011).

La multiplicité et la variabilité des facteurs de risque de développement et de maintien d'une addiction démontrent l'importance de la prise en charge pluridisciplinaire et pluri-composantes. En effet, prendre en charge ces différentes sphères permet une approche globale des patients et favorise l'amélioration des symptômes addictifs (H. S. Kim & Hodgins, 2018). Enfin, il est aussi important de modéliser ces facteurs de risque en lien avec les symptômes addictifs pour mieux appréhender les processus à prendre en charge.

1.1.5. L'importance de l'approche processuelle dans les addictions

L'approche processuelle est une évolution du modèle biopsychosocial d'Engel (Engel, 1980). Le modèle biopsychosocial avait été proposé pour améliorer la compréhension des troubles mentaux car les modèles de son époque (avant 1980) se concentraient uniquement sur les aspects biomédicaux. Dans ce modèle, les facteurs de risques biologiques (système nerveux), sociaux (relations, famille, communauté) et psychologiques co-agissent dans le développement et le maintien des troubles mentaux.

Kinderman a proposé une évolution du modèle biopsychosocial, car ce dernier manquait d'informations hiérarchiques concernant le lien de causalité entre les différents facteurs. Par ailleurs, la nature des processus psychologiques inclus dans ce modèle devait, selon lui, être explicitée (Kinderman, 2005). L'approche processuelle propose ainsi une hiérarchisation entre les facteurs évoqués ci-dessus : les facteurs biologiques et environnementaux et les expériences personnelles viendraient perturber les processus psychologiques. La perturbation de ces processus psychologiques se traduirait ensuite par un symptôme ou un trouble mental (voir Figure 1). Par exemple, une altération du système sérotoninergique pourrait agir sur la perception de l'estime de soi ou de la motivation, et engendrer un trouble dépressif. Sur le plan social, la pauvreté est liée à la dépression car ce facteur social va générer un sentiment de perte d'espoir et de désillusion, qui va ensuite entraîner les symptômes dépressifs (Kinderman, 2009).

L'approche processuelle a ainsi été utilisée pour décrire les profils de développement du JAP proposés dans la littérature (modèle intégratif des trajectoires - (Blaszczynski & Nower, 2002)) (Bonnaire & Billieux, 2022). De manière générale, les facteurs de risque comprennent des facteurs *individuels* (comme la personnalité, ou des facteurs biologiques), *interpersonnels* (style d'attachement, fonctionnement familial), *circonstanciels* (événements de vie négatifs ou environnements stressants), *écologiques* (accessibilité et disponibilité des JHA). Ces facteurs de risque viendraient interagir avec les processus psychologiques émotionnels (comme la régulation émotionnelle) et cognitifs (les capacités de contrôle inhibiteur par exemple). Ces processus psychologiques engendreraient ensuite des syndromes ou symptômes psychiatriques (Bonnaire & Billieux, 2022).

Ainsi, il est possible d'imaginer par exemple que l'isolement lié à la pandémie du COVID-19 puisse engendrer de l'ennui (-facteurs circonstanciels), ce qui peut être associé à des capacités de *self-control* diminuées (Boylan et al., 2021) (- processus psychologiques) et une augmentation de la fréquence de paris (Fluharty et al., 2022), ce qui peut favoriser le développement d'un JAP si cette situation

s'accompagne par exemple, de distorsions cognitives (ou croyances dysfonctionnelles (Bonnaire & Billieux, 2022)).

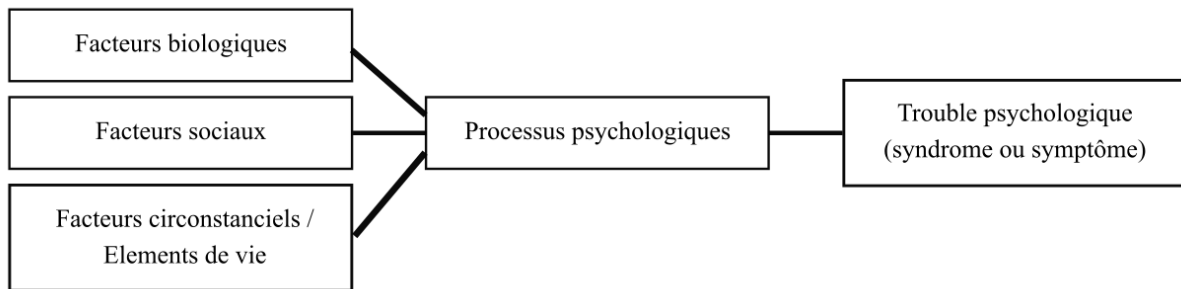


Figure 1 Le modèle processuel de Kinderman issu de Kinderman, 2009

Sur le plan scientifique, cette approche permet d'avoir un cadre de pensée préservant du risque de sur-pathologiser certains comportements de la vie quotidienne. En effet, s'intéresser aux processus sous-tendant les syndromes permet de se concentrer sur l'étiopathogénie des symptômes et non pas la pose de diagnostic en elle-même. Cela permet de rendre plus efficace le traitement car correspondant véritablement aux difficultés rapportées par les patients (Billieux et al., 2015; Bonnaire & Billieux, 2022).

1.1.6. Les modèles de compréhension des addictions

1.1.6.1. Le modèle triadique (Noël et al., 2013)

Concernant la modélisation du fonctionnement cognitif dans l'addiction, ce trouble peut être conçu comme résultant d'un déséquilibre entre 3 systèmes. Le premier système est décrit comme impulsif et automatique. C'est un système qui permet au quotidien de mettre en place des routines d'action pour limiter le coût attentionnel des tâches habituelles et automatisées (aller au travail sans avoir besoin de réfléchir au trajet par exemple). Il serait géré par un réseau incluant l'amygdale et le striatum.

Le second système est réflexif, il intervient pour contrôler les routines automatiques mises en place par le système impulsif et lors de situations non routinières, complexes ou nouvelles. C'est ce système qui contrôle les impulsions basiques et permet de poursuivre des buts à long terme. Il est composé de deux systèmes imbriqués au niveau neuronal qui gèrent d'une part des aspects « froids » (mémoire de travail, inhibition et flexibilité) et d'autre part des aspects exécutifs dits « chauds ». Ces informations exécutives « chaudes » sont les informations sensorielles ou les états somatiques issus des souvenirs et connaissances. Ces données permettent de donner un signal plutôt positif ou négatif à une situation. La prise de décision s'effectue grâce aux informations de ces deux systèmes, en pesant les avantages à court terme ou inconvénients à plus long terme.

Enfin, le système intéroceptif permet la traduction des sensations corporelles en représentations intéroceptives qui sont essentielles à la formation du ressenti subjectif. Il est géré par l'insula.

Dans les processus addictifs, une hyper activation du système impulsif serait couplée à une hypo activation du système réflexif. Le système impulsif sous-tendrait ainsi les réponses automatiques déclenchées par les stimuli liés à l'addiction ou des affects négatifs par exemple, ainsi que les processus attentionnels. Il favoriserait les comportements compulsifs en transformant des comportements dirigés vers un but, en actions réalisées indépendamment du résultat. Du fait de l'hyper activation de ce système, des biais attentionnels vers l'objet de l'addiction et des tendances d'approches automatiques apparaîtraient. L'hypo activation du système réflexif se traduirait par une altération des capacités d'inhibition et une saillance excessive attribuée à l'objet de l'addiction, ce qui expliquerait que ce dernier devienne le centre d'intérêt principal.

Enfin, le système intéroceptif allouerait les ressources normalement prévues pour le système réflexif au système impulsif (Noël et al., 2013; Wei et al., 2017). Ce système intéroceptif serait aussi essentiel dans l'apparition des envies irrésistibles caractéristiques du processus addictif.

Les ACs peuvent ainsi être décrites comme conséquence d'un contrôle exécutif altéré, d'une prise de décision aveugle aux conséquences à long terme et d'une recherche de sensation importante qui vont faire augmenter les sensations de *craving* et participer à la répétition du comportement malgré les conséquences négatives (Dong & Potenza, 2014).

En lien avec ce modèle triadique, il a été démontré des difficultés dans la prise de décision pour les patients souffrant de JAP (Balodis, 2020; Ciccarelli et al., 2017) et de JVP (Dong & Potenza, 2016; Schiebener & Brand, 2017), même si certaines études doivent encore venir compléter et confirmer cette altération (Billieux et al., 2020). Certaines revues de littérature ont par ailleurs mis en évidence une altération des capacités d'inhibition dans le JAP (Chowdhury, 2017; Ioannidis et al., 2019) et le JVP (Argyriou et al., 2017). Enfin, la présence d'un biais attentionnel vers les stimuli en lien avec l'addiction a aussi été démontrée pour le JAP (Hønsi et al., 2013) et le JVP (Metcalf & Pammer, 2011; Zhou et al., 2012). Certaines fonctions comme la flexibilité nécessitent cependant des recherches plus approfondies (Rochat et al., 2019).

1.1.6.2. Le modèle I-PACE (Interaction of Person-Affect-Cognition-Execution) (Brand et al., 2016, 2019)

En 2016, Brand et collaborateurs ont développé un premier modèle théorique (Brand, Young, et al., 2016), dénommé le modèle I-PACE (Interaction of Person-Affect-Cognition-Execution), s'attachant à décrire les processus sous-tendant le trouble de l'usage d'internet. Dans une version plus récente de ce modèle, la même équipe a étendu cette théorie à l'ensemble des ACs (Brand et al., 2019). L'objectif des auteurs était de décrire les processus psychologiques et neurobiologiques expliquant l'apparition et le maintien de comportements addictifs (voir Figure 2).

Ce modèle présente ainsi l'interaction entre les principales caractéristiques de la personne potentiellement impliquées dans le processus addictif en tant que variables de prédisposition (composant P - personne) et le cycle interne du processus addictif (composants A-C-E ; pour Affect, Cognition et Exécution respectivement). Le modèle est décliné en deux parties, la première représentant les stades précoces et décrivant les processus impliqués dans la réalisation des comportements avant l'apparition d'une addiction, et la seconde modélisant des stades plus avancés décrivant les processus mis en œuvre au stade de l'addiction.

Quel que soit le stade, le composant P comprend des variables de prédisposition, générales ou spécifiques du comportement, qui ont été majoritairement retrouvées dans la littérature comme pouvant influencer le développement et le maintien d'une addiction (traumatisme vécu dans l'enfance, dépression, anxiété, impulsivité). Le cycle interne A-C-E évolue quant à lui en fonction du stade du processus addictif.

Aux stades précoces, lorsque des stimuli externes ou internes sont perçus, des réponses affectives et cognitives sont produites et déclenchent des envies de réaliser le comportement spécifique, ou une attention accrue envers ces stimuli. La prise de décision (de réaliser ou non le comportement spécifique et qui résulte de la balance entre les systèmes impulsif et réflexif) est modulée par des capacités de contrôle inhibiteur encore opérant et les capacités d'auto-régulation. Le comportement engendre principalement de la satisfaction et parfois du soulagement (par compensation des affects négatifs).

Au fur et à mesure de la répétition du comportement, les attentes liées à la réalisation de la conduite spécifique vont évoluer. Cette répétition peut aussi modifier les styles de *coping* (stratégie de gestion des émotions désagréables). Par exemple, au fur et à mesure de la répétition, la personne va apprendre que jouer aux JV génère des affects positifs, voire soulage des affects négatifs et permet de se sentir moins triste. Et finalement, le sujet peut généraliser le lien entre JV et régulation des émotions, en pensant que jouer aux JV peut être une source de plaisir importante et peut permettre de gérer tous les affects désagréables de la vie quotidienne. Il y a donc un changement de perception des attentes liées à la réalisation du comportement et des stratégies de coping quotidiennes. Cette évolution va favoriser les envies importantes de réaliser le comportement suite à l'exposition à des stimuli déclencheurs (externes ou internes). Cette association entre éléments déclencheurs et envies s'intensifie au fur et à mesure de la répétition du comportement, ce qui rend le contrôle inhibiteur concernant le comportement spécifique plus difficile. Les capacités d'inhibition agissent comme un médiateur dans les stades les plus avancés, et leur diminution participe au fait que la réalisation du comportement spécifique devienne une habitude. La décision d'agir est désormais une réponse impulsive suite aux indices déclencheurs.

A. Stades précoces

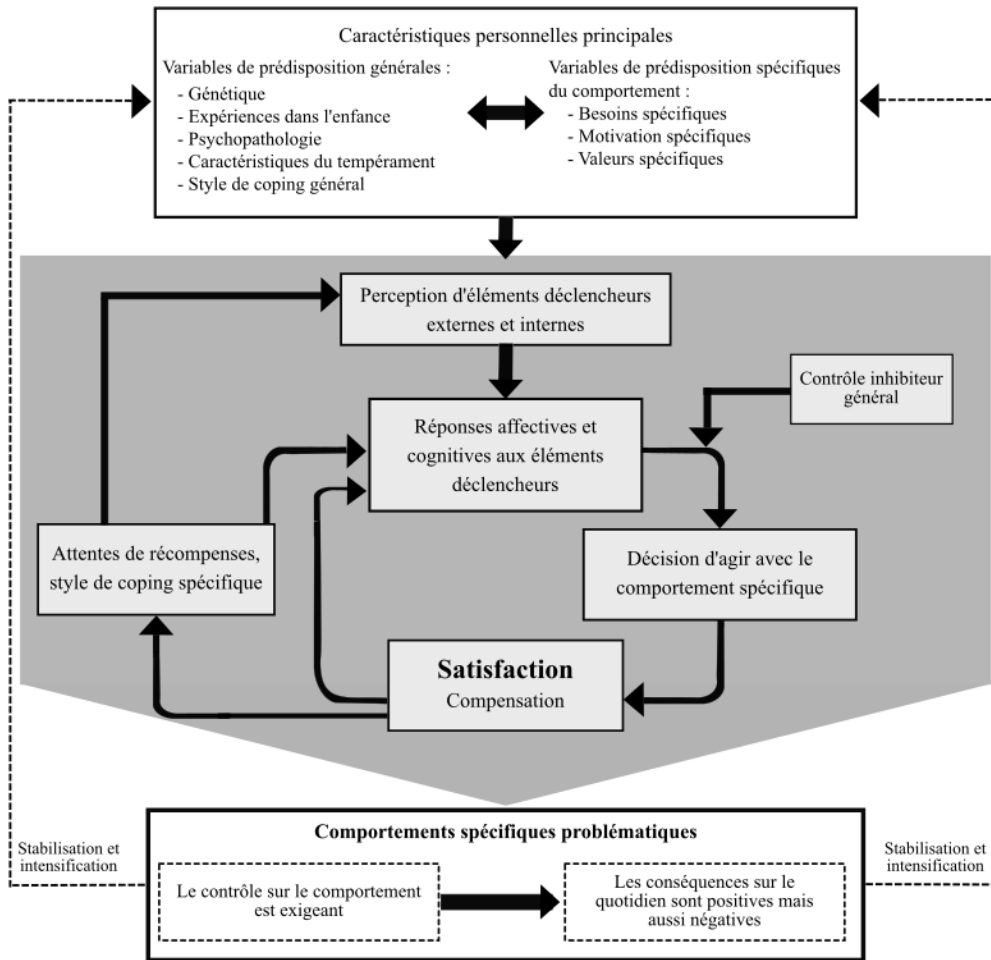
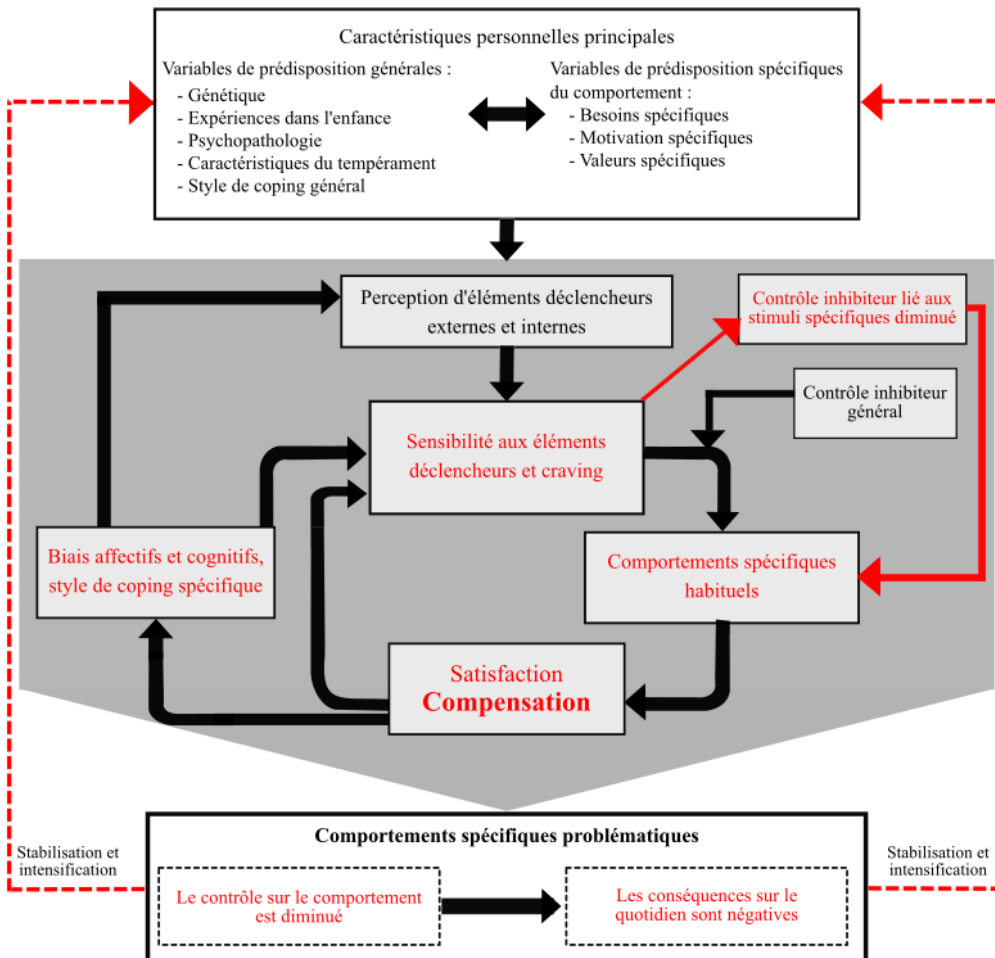


Figure 2 Figure traduite et issue de l'article de Brand 2019 révisé.

La partie A montre les étapes de développement de l'addiction et la partie B illustre les étapes plus tardives participant au maintien de l'addiction. Les flèches plus épaisses montrent une relation plus forte, les éléments en rouge sont ceux qui diffèrent entre les stades précoces et les stades ultérieurs. Coping = stratégie d'adaptation face aux émotions négatives.

B. Stades ultérieurs



Ainsi, dans les stades plus avancés du processus addictif, l'association entre stimuli déclencheurs, réponse impulsive et récompense se renforce jusqu'à devenir un comportement habituel quasi automatique. Les réponses affectives et cognitives face aux stimuli déclencheurs se transforment en une sensibilité accrue et engendrent du *craving*, tandis que les attentes liées à la réalisation du comportement se transforment en biais cognitifs (et notamment attentionnels) et affectifs. Enfin, le comportement réalisé l'est pour compenser les conséquences négatives sur la vie. La gratification liée à la réalisation du comportement est ainsi remplacée progressivement par de la compensation et la répétition du comportement problématique renforce les biais et les styles de coping.

1.1.7. Une prise en charge possible des processus addictifs : le modèle trans-diagnostique de traitement

Sur le plan clinique, la prise en charge des processus addictifs et non pas d'une addiction en particulier va ainsi favoriser l'exploration des processus psychologiques et de la compréhension des causes des comportements. Cela permet aux cliniciens de ne pas se concentrer uniquement sur le diagnostic ou la prise en charge d'un trouble discret (Kinderman & Tai, 2007) et ainsi de travailler sur les mécanismes de fond et non pas sur les symptômes apparents.

Cette vision processuelle théorique sert ainsi de support à une approche pragmatique du traitement qui soit commune aux ACs mais aussi aux TUS, de manière à faciliter le travail des cliniciens, mais aussi à favoriser l'amélioration des comorbidités qui sont très fréquentes dans les addictions (H. S. Kim & Hodgins, 2018). Ce modèle trans-diagnostique propose ainsi de travailler sur les facteurs trans-diagnostiques aux différentes addictions et notamment :

- L'ambivalence quant au changement de comportement peut être résolue grâce à l'entretien motivationnel,
- L'urgence négative (facette de l'impulsivité en réaction à des affects négatifs) peut être prise en charge par une thérapie de type *mindfulness* (méditation en pleine conscience),
- Le déficit d'auto-régulation, en lien avec le fonctionnement exécutif altéré peut être amélioré en entraînant les capacités d'inhibition (Verdejo-Garcia et al., 2019),
- Les capacités de mémoire de travail sont régulièrement altérées dans le TUS et peuvent aussi être une cible thérapeutique pour améliorer les capacités de fonctionnement au quotidien grâce à des exercices écologiques (Rochat & Khazaal, 2019),
- La surcharge cognitive et émotionnelle engendrée par le déficit exécutif peut être prise en charge grâce à de la thérapie basée sur la résolution de problèmes, en apprenant à utiliser des réponses structurées à des problèmes,
- Les croyances dysfonctionnelles (croyances permissives et anticipatoires telles que « j'ai eu une grosse semaine j'ai le droit » ou « si je joue je vais aller mieux ») peuvent être prises en charge

avec la restructuration cognitive via une thérapie cognitivo-comportementale (TCC), qui représente le gold standard dans ce cas ;

- L'entraînement aux capacités de coping est également important pour limiter les stratégies dysfonctionnelles de coping,
- Le déficit de support social peut être amélioré grâce aux groupes de support entre pairs, de type *gamblers anonymous*, avec un parrain, ou par des thérapies familiales ou de couple,
- Enfin, la compulsivité, et les comportements de persévération qui émergent au fil du temps et vont maintenir l'addiction, peuvent être pris en charge en travaillant par exemple sur la diminution des biais attentionnels (*cognitive bias modification* – travailler sur les biais attentionnels via des tâches informatisées telles que la Visual Dot Probe task, cette approche semblant avoir un effet positif sur le taux de rechute (Boffo et al., 2019) dans le TUS).

Ce programme de PEC est modulable et toutes les composantes peuvent être proposées, en prise en charge individuelle ou de groupe, grâce à un programme flexible et adapté à l'objet de l'addiction et à chaque individu. Par exemple, pour le JAP, on travaillera plus volontiers sur les pertes financières. Par ailleurs, il apparaît important d'adapter la prise en charge en fonction de la présence d'une comorbidité psychiatrique. En effet, en présence de ce type de comorbidité (trouble de l'usage de l'alcool, trouble de l'humeur), un traitement médicamenteux (naltrexone, lithium – en cas de diagnostic de bipolarité, ou des inhibiteurs de recapture de la sérotonine pour d'autres troubles de l'humeur) peut-être proposé en addition d'une prise en charge TCC, ou plus brève si le patient n'est pas prêt à s'engager dans une thérapie plus intensive (Potenza et al., 2019).

Cette approche processuelle permet ainsi de comprendre l'addiction d'un point de vue global plutôt que de prendre en charge des addictions de façon distincte. Cela permet de développer des pistes thérapeutiques ou préventives bénéfiques à l'ensemble des addictions et de prendre en compte les switches d'une addiction à l'autre qui peuvent apparaître au décours du parcours addictif.

Enfin, concernant plus particulièrement la prise en charge des altérations cognitives, il est possible de travailler ces difficultés via de la remédiation cognitive (RC). La RC est un entraînement cognitif d'une ou plusieurs fonctions cognitives dans un but d'amélioration, de durabilité et de généralisation (Wykes et al., 2011). Cependant, la mise en place de la RC nécessite des outils et une expertise neuropsychologique, qui manquent actuellement en clinique (Billieux & Maurage, 2021). Aujourd'hui, la prise en charge est centrée sur le diagnostic, et les outils de RC sont ceux utilisés dans le TUS, sans prendre en compte la spécificité des ACs (Billieux & Maurage, 2021; Challet-Bouju et al., 2017).

1.1.8. Aspect social des addictions

Les modèles théoriques de compréhension et de prise en charge des addictions soulignent l'importance des relations sociales dans le déclenchement et le maintien de l'addiction. Le fait de ressentir un manque de soutien social (Paulus et al., 2018), ou un sentiment d'isolement ou de solitude font partie des facteurs de vulnérabilité individuels qui vont entrer en jeu dans les variables de prédisposition et de maintien (Brand et al., 2019). Les relations avec les parents semblent se dégrader en lien avec le déclenchement du JVP (Gentile et al., 2011) et des difficultés sur le plan familial ont été démontrées dans le JAP (Black et al., 2012; Cowlishaw et al., 2016). Ces différentes données rapportées par les patients ne permettent cependant pas de caractériser la direction de causalité entre pratique addictive et difficultés interpersonnelles. En effet, il est possible que certaines personnes disposent de capacités de création et de maintien de lien social moindres, qui participent au risque de développer des comportements addictifs. A l'inverse, il semble aussi possible que la pratique excessive d'un comportement impacte négativement la qualité des rapports sociaux et engendre des difficultés relationnelles du fait de la répétition du comportement. Enfin, les difficultés interpersonnelles et les comportements addictifs peuvent être dans une dynamique de synergie et s'entretenir l'un avec l'autre.

Finalement, comme souligné dans les modèles explicatifs des processus addictifs, le fonctionnement cognitif occupe une place essentielle dans notre compréhension des troubles. Il est ainsi important de pouvoir caractériser objectivement les capacités de traitement des informations sociales, c'est-à-dire la cognition sociale (CS) des patients présentant une AC. En effet, coupler un recueil du ressenti des patients *via* des auto-questionnaires avec une évaluation neuropsychologique standardisée des compétences en cognition sociale (CS) permet d'obtenir une vision unifiée des forces et difficultés retrouvées dans les ACs, pour améliorer d'une part la prise en charge et d'autre part les modèles de compréhension.

1.2. La cognition sociale (CS)

1.2.1. Origine du concept

La CS est un concept à la frontière entre la psychologie, les neurosciences, l'anthropologie et la sociologie. Ce concept regroupe toutes les fonctions qui permettent de décoder et d'encoder le monde social. Dans sa plus large définition, il est possible d'inclure 3 classes de fonctions : celles qui permettent de percevoir (différents niveaux possibles de perception, avec un lien avec les données stockées en mémoire et le contexte), celles qui permettent de comprendre le soi comme objet social (et notamment en se considérant comme un objet social à comprendre pour comprendre les autres) et enfin les connaissances sociales interpersonnelles (normes ou compétences procédurales) (Beer & Ochsner, 2006).

1.2.2. Les composantes pouvant être incluses dans ce concept

Il est ainsi possible de définir la CS comme un ensemble de fonctions cognitives qui sous-tendent toutes les relations sociales et permettent de répondre de manière socialement adaptée (Adolphs, 2001; Frith, 2008; Saxe, 2006). Ce concept couvre donc un large spectre de fonctions, qui peuvent être d'un niveau très basique, automatique ou subliminal, jusqu'à des fonctions plus complexes et contrôlées comme la compréhension de l'ironie (Beer & Ochsner, 2006; Bertoux, 2016; Greifeneder et al., 2017). Cependant, en fonction des cadres de pensée et des auteurs, la définition du concept n'est pas consensuelle notamment s'agissant des composantes à intégrer à la CS (Achim et al., 2020). Il existe ainsi différents modèles qui intègrent de plus ou moins nombreux éléments à la définition de la CS (Fiske & Taylor, 2016; Green et al., 2015; F. Happé & Conway, 2016).

1.2.3. Les modèles de compréhension de la CS

1.2.3.1. Le modèle factoriel

L'exploration systématique de la littérature (Etchepare & Prouteau, 2017) a montré que la CS pouvait être conceptualisée grâce à une analyse factorielle sur deux axes. Le premier axe sépare les tâches ou fonctions ayant un niveau de traitement bas (identifier une émotion sur un visage) ou élevé - compréhension plus approfondie comme la théorie de l'esprit (TdE, i.e., attribuer un état mental pour prédire et comprendre le comportement d'autrui (Premack & Woodruff, 1978))) (Adolphs, 2009, 2010; Etchepare & Prouteau, 2017; Frith & Frith, 2008). Le second axe sépare les tâches ou fonctions selon la nature du stimuli (qui peut être affective lorsqu'un aspect émotionnel est inclus, ou cognitive –sans aspect émotionnel) (Adolphs, 2010; Etchepare & Prouteau, 2017; McDonald, 2013; S. G. Shamay-Tsoory & Aharon-Peretz, 2007).

Par ailleurs, dans ce modèle, l'alexithymie est décrite comme un trait normalement distribué, un haut niveau de ce trait correspondant à un pôle extrême dans la conscience de ses propres émotions. La CS y

est aussi vue comme une fonction cognitive à part entière qui n'est pas complètement dépendante du niveau de neurocognition (i.e, les fonctions cognitives n'étant pas dans le spectre de la CS).

1.2.3.2. Le modèle intégratif 8-SIF-B (Eight Sources of Information Framework bonifié)

La TdE peut être modélisée sur deux niveaux. La TdE de premier ordre correspond au fait d'attribuer à une personne un état mental lié à une réalité physique : c'est par exemple une croyance au sujet de la localisation d'un objet (le personnage A pense que l'objet est situé dans le placard) ; tandis que la TdE de second ordre correspond au fait d'attribuer à une personne un état mental sur l'état mental d'une autre personne : c'est par exemple la croyance d'une personne A au sujet de la croyance d'une personne B (le personnage A pense que le personnage B pense que l'objet est situé dans le frigidaire).

Le modèle princeps (8-SIF : Eight Sources of Information Framework) au modèle intégratif 8-SIF-B (Eight Sources of Information Framework bonifié) cherchait à caractériser uniquement le fonctionnement de la TdE. Le modèle 8-SIF (voir Tableau 2) théorise ainsi les sources d'informations sur lesquelles il est possible de s'appuyer pour inférer ces différents états mentaux. Dans ce modèle, 8 sources d'informations sont présentées. Ces informations sont indiquées comme pouvant être stockées immédiatement (i.e., sont perçues ou issues du langage) ou provenant de la mémoire du sujet (en lien avec la situation spécifique ou bien avec des informations plus générales comme des normes). Toutes ces informations peuvent concerner la personne observée ou le contexte de la situation (Achim et al., 2013).

Tableau 2 Les 8 sources d'information (8-SIF) - Traduction issue de l'article d'Achim, 2013

		Agent	Contexte
Immédiat	Perception	I1	I3
	Langage	I2	I4
Stocké	Spécifique de la source	S1	S3
	Général	S2	S4

Le modèle 8-SIF-B intègre ainsi les 8 sources d'informations de la TdE et fait le lien avec les différentes fonctions cognitives qui permettent de fonctionner socialement et qui représentent la CS (voir Figure 3). Dans ce modèle, les informations perçues lors de la situation sociale (émotions faciales, informations non verbales) sont tout aussi pertinentes que celles emmagasinées en mémoire (au sujet de la personne ou du contexte) pour inférer un état mental. Cependant, la récupération de ces informations est soumise au fonctionnement d'autres habilités cognitives non sociales (telles que l'attention, la mémoire ou encore le fonctionnement exécutif). Une attribution correcte d'états mentaux permet ensuite d'ajuster le comportement social (incluant par exemple les capacités de réciprocité sociale). La réciprocité sociale correspond au fait de réagir de manière appropriée dans une relation sociale en fonction des indices

affichés par la personne (Constantino et al., 2000; Pinkham et al., 2014). La relation entre la TdE et l'ajustement du comportement social peut être impactée par le style attributionnel (qui reflète la façon dont les individus attribuent la causalité des événements) et qui peut être biaisé. Un ajustement du comportement social permet ensuite de fonctionner socialement au quotidien (Achim et al., 2020).

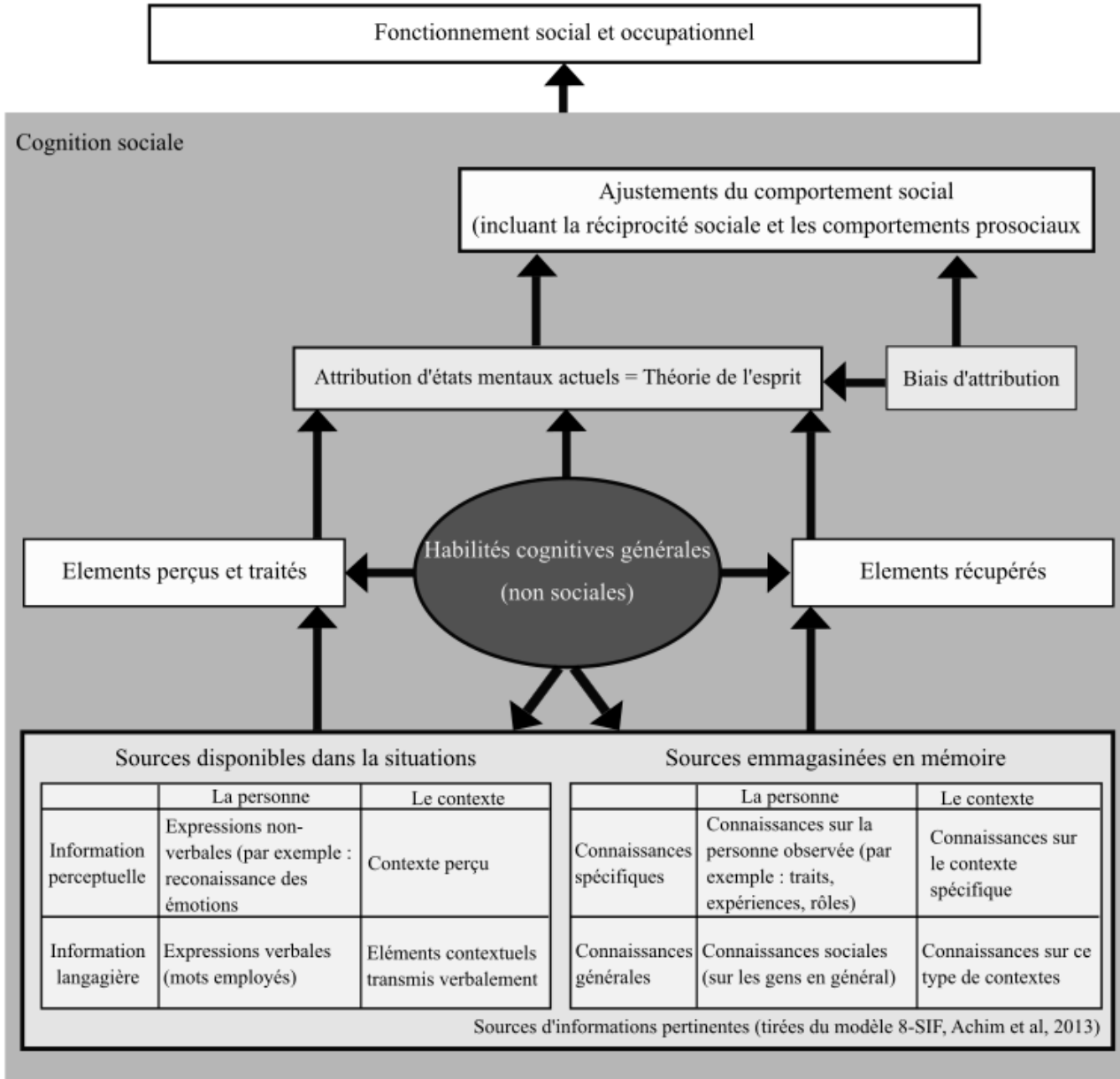


Figure 3 Modèle intégratif 8-SIF bonifié issu d'Achim, 2020

1.2.3.3. Lien entre cognition sociale et addictions

Les interactions entre CS et addictions ont surtout été étudiées chez les sujets souffrant d'un TUS. Dans son modèle qualifié de circulaire, Quednow théorise le déficit de CS dans le TUS. Pour cet auteur, l'ingestion chronique de substances neurotoxiques engendre des changements neuronaux dans les

systèmes de récompense et les réseaux sous-tendant les fonctions de CS. Ces changements cérébraux vont générer des difficultés sur le plan de la CS, et donc une altération du comportement prosocial et de la réponse à la récompense sociale. Ces altérations vont engendrer une diminution des contacts et du support social, et une augmentation de l'isolement social, des comportements agressifs et des symptômes dépressifs, provoquant une diminution des ressources pouvant donner lieu à de la récompense sociale. Un retrait social apparaît ainsi, ne laissant plus que l'utilisation de substances comme source de récompense/plaisir. Cela a pour conséquence de maintenir l'utilisation des substances et de favoriser les rechutes (Quednow, 2017).

En lien avec ce modèle, des recherches empiriques concernant le TUS et la CS ont démontré une altération des capacités de reconnaissance des émotions dans le trouble de l'usage de l'alcool. Cette altération semble liée à l'ingestion d'alcool (D'Hondt et al., 2021; Quednow, 2020), ainsi qu'à une altération des processus visuels, en lien avec un défaut de communication occipito-frontale observé dans cette population (Creupelandt, D'Hondt, et al., 2021; Creupelandt, Maurage, et al., 2021). En outre, il a été démontré, toujours dans un groupe de patients présentant un trouble de l'usage de l'alcool, que le niveau de capacité de reconnaissance des émotions faciales pouvait prédire la rechute ou l'arrêt prématuré des soins (Rupp et al., 2017).

Dans les ACs, il est encore difficile d'acter sur la hiérarchie entre difficultés de CS et développement d'une addiction. Si l'on considère que les difficultés de CS sont présentes avant l'addiction, alors ces difficultés pourraient engendrer une altération des comportements de réciprocité sociale et donc de la qualité des relations, ce qui altérerait le support social et favoriserait l'isolement. Cet isolement engendrerait une diminution des ressources sociales et des expériences de récompense sociale. *In fine* le retrait social pousserait à la répétition du comportement spécifique et engendrerait par la suite des changements neuronaux du système de récompense et de la CS, qui majoreraient les difficultés de CS.

De manière réciproque, si l'on considère que les difficultés de CS apparaissent en lien avec la répétition du comportement, alors on peut supposer un modèle en deux temps comme proposé par Brand (Brand et al., 2019). Au début des processus addictifs, les capacités de CS seraient préservées, mais la répétition du comportement et la transition vers l'addiction modifieraient le système de récompense et par conséquent les capacités de CS. En effet, le système de récompense et la CS seraient sous-tendus par des réseaux neuronaux communs incluant notamment le cortex cingulaire antérieur, l'insula et le striatum ventral (Brand et al., 2019; Feng et al., 2021). Ces altérations pourraient engendrer des difficultés sur le plan de la CS, ce qui viendrait impacter les capacités d'ajustement. *In fine*, le support social diminuerait, favorisant l'isolement et réduisant les expériences de récompense sociale, engendrant ainsi le retrait social. La répétition du comportement spécifique serait alors la seule source de récompense/de plaisir et cela favoriserait le maintien du comportement addictif.

1.2.4. Prise en charge de la CS

La prise en charge de cette composante du fonctionnement cognitif semble ainsi être un enjeu majeur de la prise en charge des addictions. Il existe des programmes de RC spécifique de la CS. Par exemple, ce type de RC est proposé à des patients présentant un diagnostic de schizophrénie (Horan & Green, 2019; Kurtz et al., 2016), avec notamment des programmes spécialisés tels que *le Social Cognition and Interaction Training* (SCIT) (Penn et al., 2005). La RC axée sur la CS peut aussi être proposée dans la prise en charge des traumatismes crâniens (Vallat-Azouvi et al., 2019) ou encore dans l'autisme (Eack et al., 2018). Une prise en charge en RC peut parfois être associée à de la TCC (Kukla et al., 2018). Dans les TUS, la RC axée sur le fonctionnement cognitif global est citée comme traitement prometteur (Nardo et al., 2022), et il a été démontré l'importance de prendre en compte la CS dans l'évaluation et la réhabilitation neurocognitive des patients ayant un trouble de l'usage d'alcool, et de considérer des programmes incluant la remédiation des compétences émotionnelles et sociales. Cependant, ces recommandations ne semblent pas avoir encore été appliquées (Billieux & Maurage, 2021; Le Berre, 2019).

Conclusion de la première partie

La première partie de ce travail de thèse a permis de délimiter les concepts d'AC et de CS, mais aussi d'en montrer les limites. Ces deux sujets sont en effet contemporains et en constante évolution.

Le fonctionnement cognitif a un rôle majeur dans notre compréhension des processus addictifs, et fait partie des facteurs de risque et de vulnérabilité de l'addiction. La CS fait partie du fonctionnement cognitif, mais est très peu étudiée, alors que les indices cliniques suggèrent des difficultés de fonctionnement social pour les patients, et qu'il est possible de proposer de la RC en tant que traitement complémentaire aux thérapies existantes.

Ce travail de thèse questionne ainsi le lien entre CS et AC : existe-t-il une altération des capacités de CS dans les ACs ? Comment cette question a-t-elle été étudiée dans la littérature ? Que sait-on du profil de CS dans les ACs ? Y a-t-il des points communs entre ACs ou avec les TUS ?

La seconde partie de ce travail de thèse s'attachera ainsi à présenter les états systématiques de l'art concernant les deux ACs reconnues dans la littérature internationale (le JAP et le JVP). La troisième partie, quant à elle, présentera les travaux menés au cours de ces quatre années qui ont permis d'alimenter la littérature concernant les ACs et la CS. Enfin, une quatrième et dernière partie discutera ces différents résultats qui seront mis en perspective.

PARTIE 2. ETAT DE L'ART

Cette partie inclut deux revues systématiques de la littérature. La première répertorie tous les articles faisant le lien entre JAP et CS. La seconde s'intéresse aux recherches menées au sujet de la CS et de la pratique du JV. Ces deux revues se concentrent uniquement sur l'évaluation de la CS par des tâches neuropsychologiques.

Articles présentés dans cette partie :

- Manuscrit 1 publié dans *Current Addiction Reports* :

Hurel, E., Challet-Bouju, G., Bukowski, N., Eyzop, E., & Grall-Bronnec, M. (2019). Gambling and Social Cognition: A Systematic Review. *Current Addiction Reports*. <https://doi.org/10.1007/s40429-019-00280-0>

- Manuscrit 2 : soumis dans *Neuropsychology Review* :

Hurel, E., Grall-Bronnec, M., Bouillard, O., Chirio-Espitalier, M., Barrangou-Pouey-Darlas, M., & Challet-Bouju, G. Social cognition and gaming, what do neuropsychological data tell us? A systematic review of neuropsychological assessment of social cognition and gaming. Under review.

- ❖ Revue systématique présentée lors du congrès du GREPACO (Groupe de Réflexion en Psychopathologie Cognitive), le 31 mai et 1^{er} juin 2021, en visio-conférence, intitulé :
« Revue de la littérature sur cognition sociale et pratique des jeux vidéo : apport des données neuropsychologiques »

Les deux revues systématiques ont été présentées *via* un poster au 13^{ème} congrès international de l'Albatros, du 5 au 7 juin 2019, à Paris, sous le titre : « Cognition sociale dans l'addiction aux jeux vidéo et aux jeux de hasard et d'argent : revue systématique ».

2.1. MANUSCRIT 1 : Revue systématique explorant l'évaluation de la cognition sociale dans le jeu d'argent pathologique (JAP)

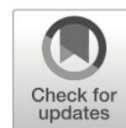
2.1.1. Résumé en français du manuscrit 1

Cette première revue de littérature avait pour but de recenser toutes les recherches liant CS et JAP. L'objectif était de mieux appréhender le profil de CS dans cette AC et de discuter les possibles pistes de RC. En effet, de nombreuses recherches sur la CS ont été menées au sein de la population de patients présentant un TUS. Nous voulions ainsi savoir si le même genre d'études avait été menées auprès de patients souffrant de JAP, et s'il était possible de proposer des pistes de prise en charge de certaines composantes de la CS grâce à ces potentielles études.

Les mots clés en lien avec le JAP et la CS ont été croisés et la recherche a été menée dans 3 bases de données (PsycINFO, PubMed and ScienceDirect). Les critères d'inclusion des articles étaient (i) d'utiliser des tâches neuropsychologiques évaluant une composante de la CS et (ii) inclure des sujets avec un diagnostic de JAP. Très peu de restrictions ont été appliquées concernant la population évaluée (outil diagnostic, patients ou non) ou les tâches utilisées car nous voulions trouver un maximum d'articles possibles.

Cette recherche systématique a permis de trouver un article évaluant la capacité de traitement des émotions non-verbales dans un groupe de patients avec un diagnostic de JAP (Kornreich et al., 2016). Dans cet article, 22 patients étaient comparés à 22 sujets contrôles appariés en âge et niveau d'études. La tâche proposée aux sujets était composée de trois modalités : l'identification d'émotions dans des extraits musicaux, des extraits vocaux et des visages. Les participants devaient aussi coter l'intensité des émotions présentées. L'analyse des performances de chaque groupe a montré que les patients présentaient des difficultés dans le jugement d'intensité pour les stimuli neutres sur les trois modalités. Par ailleurs, les patients identifiaient moins bien l'émotion présentée (quelle que soit l'émotion) lorsqu'elle était exprimée sur un visage ou *via* une voix en comparaison du groupe contrôle.

Cette revue systématique montre ainsi la rareté des études neuropsychologiques au sujet de la CS dans le JAP mais suggère que des altérations peuvent exister sur le plan du traitement des informations non verbales. Par ailleurs, certaines données rapportées par les patients ont montré *via* l'utilisation de l'IRI des difficultés d'empathie (Tomei et al., 2017). Cependant, il est nécessaire de confirmer ces résultats *via* de plus amples études. L'importance de l'alexithymie et de l'étude du genre est aussi importante et à mesurer car pouvant faire varier les capacités de CS (Grynberg et al., 2012).



Gambling and Social Cognition: a Systematic Review

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2.1.2. Abstract

Purpose of Review The aim of this article was to review current research regarding social cognition (SC) in gambling disorder (GD), to (i) compile and synthesize the current state of existing literature on this topic, and (ii) propose cognitive remediation therapy approaches focused on SC for clinicians.

Recent Findings It is well known that disordered gamblers show impairment regarding non-social cognitive functions such as inhibition, attention, and decision-making. Furthermore, patients with substance use disorders also present certain deficits regarding social information processing which are difficult to differentiate from the intrinsic toxic effects linked to drugs or alcohol consumption.

Summary To date, relatively little research has been undertaken to explore SC in GD with neuropsychological tasks. Preliminary results suggest impaired non-verbal emotion processing, but only one study has directly measured SC in GD. As a consequence, future research on this framework should propose diverse measures of SC, while controlling for other factors such as personality traits and subtypes of disordered gamblers.

Keywords Gambling disorder – Social cognition – Facial emotion processing –neuropsychology

2.1.3. Introduction

Gambling disorder (GD), formerly known as “Pathological gambling” (PG) (American Psychiatry Association, 2013), has been newly classified in the DSM-5 in the “Substances-related and addictive behavior” section. This diagnostic classification defines GD as a loss of control over behavior and repetition of the problematic behavior despite its negative consequences on social, professional, or family spheres. The repetition may be to obtain pleasure, or to relieve an internal discomfort (Goodman, 1990).

Comprehension of addiction phenomena traditionally relies on numerous risk factor models. Olievenstein’s model, for example, postulates that there are three types of risk factors that could trigger or maintain addiction: (1) the context (socio-demographical factors for example), (2) the addiction’s object (and its availability) and (3) the individual (Olievenstein, 1984). Neurocognitive functioning is part of this third factor, and can be further subdivided into three components: (i) the impulsive system, which is an automatic system handling routine situations; (ii) the reflective system, which allows an individual to act and react appropriately to new situations and make complex decisions (Burgess & Simons, 2005); and (iii) the interoceptive system, which translates physical sensations into subjective information to provide information about risks or rewards in complex situations (Noël et al., 2013).

Regarding the reflective system more specifically, two ways of processing can be distinguished. On the one hand, the “cool executive functioning” is underlied by dorsolateral frontal networks and handles executive functions dealing with emotionally neutral information. On the other hand, the “hot” executive component is underpinned by the ventromedial prefrontal cortex (VMPFC) and paralimbic orbitomedial structures. This network is in charge of provoking bodily sensations

based on experience from situations resembling the actual context, and on memory and knowledge, to give a global sensation that can then guide the decision-making process considering cognitive and emotional information (Noël et al., 2013; Zelazo & Carlson, 2012).

Addictive behavior is thus described as an imbalance of these systems, namely impulsive system hyperactivity and reflective system hypo-activity, while the interoceptive system would be impaired as well by redirecting resources from the reflective system to the impulsive system, leading to a control deficit and thus increasing allocation of resources to gambling (Noël et al., 2013).

Using this framework, therefore, behavioral addiction research has mainly focused on cool cognitive functions, highlighting alterations in attention processing, inhibition, flexibility, and decision-making (Challet-Bouju et al., 2017; Ciccarelli et al., 2017; Fauth-Bühler et al., 2017; Vizcaino et al., 2013) and linking it with neurological bases (Potenza, 2014). In contrast, little is known about hot functions in GD (Challet-Bouju et al., 2017). It has been shown that individuals with GD show specific patterns of response (Cavedini et al., 2002) and neuronal connectivity (Genauck et al., 2017) in an affective decision-making task, suggesting an alteration of the functioning of the hot network, and more specifically, the VMPFC. This brain area is also involved in affective theory of mind (ToM) functioning (S. G. Shamay-Tsoory et al., 2005) which is the ability to infer emotions to one and others (Premack & Woodruff, 1978) and is included in the broader concept of social cognition (SC) (Couture et al., 2006). SC is a broad term that regroups various functions that allow an individual to perceive and understand social information and construct efficient social relationships (Adolphs, 2001; Green et al., 2015). According to the model of Strack & Deutsch, this ensemble of functions can be classified as a dual

processing using both reflective and impulsive systems (Deutsch, Roland & Strack, 2006; Evans, 2008; Strack & Deutsch, 2004). Table 3 defines several SC functions, presents measures that may be used to assess them in a clinical context, while highlighting those corresponding to neuropsychological tasks. The primary objectives of neuropsychological tasks are to “(i) detect neurological dysfunction and guide differential diagnosis, (ii) characterize changes in cognitive strengths and weaknesses over time, and (iii) guide recommendations regarding everyday life and treatment planning” (Casaletto & Heaton, 2017).

Thus, those tasks are objective measures of cognitive performances and can be opposed to PRO (patient-reported outcomes) that are “direct subjective assessment by the patient of elements of their health” (Rothman et al., 2007). Such measures mainly assess emotion recognition and ToM abilities (Henry et al., 2015). Moreover, SC has mainly been investigated in psychiatric conditions such as autism spectrum disorder (Pelphrey et al., 2004) or schizophrenia (Green et al., 2015). It has been acknowledged as a mediator between social functioning and cool neurocognition (Couture et al., 2006). Furthermore, SC abilities have also been shown to be more correlated to social functioning than to cool cognitive functioning, in a population of patients with schizophrenia (Couture et al., 2006; Fett et al., 2011), and in a population of patients with traumatic brain injury (Ubukata et al., 2014).

Regarding addictions in general, patients with alcohol use disorder are impaired in processing facial emotions (Donadon & de Lima Osorio, 2014), and patients with substance use disorder show lower levels of emotional empathy than control subjects (Bora & Zorlu, 2016; Ferrari et al., 2014; Mauraige, Grynberg, Noël, Joassin, Philippot, et al., 2011). Nevertheless, it is difficult to differentiate alterations linked to the intrinsic toxic effect of drugs or alcohol from dysfunction linked to an addiction mechanism, even if functional imaging

research has suggested that cerebral markers exist before the onset of addictive behavior (Glahn et al., 2007). Studying neurocognitive alterations of patients suffering from behavioral addictions may allow the identification of SC deficits due to the addictive vulnerability rather than those caused by the intake of exogenous neurotoxic substances. Moreover, direct measures such as neuropsychological tasks may avoid biases in the measurement of SC, as is the case with self-reported scales, which rather assess the perception of one's social abilities, i.e., social metacognition.

Previous research has shown that individuals with subclinical forms of pathological gambling (i.e., those who gambled and met 2–3 criteria of the DSM-IV) scored lower than controls on a psychosocial functioning scale (Weinstock et al., 2017). Nevertheless, the relationship between GD, social functioning and SC is still unclear. SC is a factor that could trigger, maintain or cause relapse of the GD. The aim of this article was to review recent research on SC and GD, based on a systematic review investigating the link between SC abilities and disordered gambling using a direct neuropsychological measure of SC. The objectives were to (i) characterize SC deficits linked to non-substance addiction, and synthesize the current state of existing literature on this topic and (ii) further understand the profile of individuals with GD, which could also hopefully provide guidance regarding cognitive remediation therapies focused on SC for health care professionals.

2.1.1. Method

Search strategy

The research strategy follows instructions of the Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement (Moher et al., 2009).

Research was performed using three databases (PsycINFO, PubMed and ScienceDirect). A combination of key words and MeSH (Medical Subject

Tableau 3 Non-exhaustive list of social cognition (SC) components and their possible assessment - Manuscrit 1

SC components	Definition	Tools that can assess them
Non Verbal Emotion processing	Ability to perceive and identify emotion in others, and to react and feel appropriately (Phillips, 2003)	<u>Ekman Faces</u> (Bertoux et al., 2012; Ekman & Friesen, 1976) <u>Florida Affect Battery</u> (FAB) (Bowers et al., 1999) <u>Emotion Evaluation Test</u> (EET) (in The Awareness of Social Inference Test, TASIT (McDonald et al., 2003))
Empathy	Ability to feel/share (<i>affective component</i>) and understand (<i>cognitive component</i>) emotions of others, and ourselves (<i>self-awareness</i>).	IRI questionnaire (Interpersonal Reactivity Index) : self-report questionnaire exploring four dimensions : <ul style="list-style-type: none"> • <i>Fantasy</i> (FT) which assesses the capacity to imagine oneself into fictional scenes or characters, • <i>Perspective-Taking</i> (PT) which assesses the ability to understand the point of view of someone else, • <i>Empathic Concern</i> (EC) which evaluates the capacity to resent concern and compassion towards others, • <i>Personal Distress</i> (PD), which assesses the tendency to resent anxiety in a tense social situation (M. Davis, 1980; Tomei et al., 2017). <p>In the IRI questionnaire, EC and PD scales are part of the affective component of empathy, while the cognitive component is assessed by PT and FT scales (Decety & Moriguchi, 2007; Ferrari et al., 2014; Maurage, Grynberg, Noël, Joassin, Philippot, et al., 2011).</p> <p><u>LEAS</u> (Levels of Emotional Awareness) (self-awareness) (Bydlowski et al., 2002)</p>
Theory of Mind (ToM)	Capacity to attribute mental states in order to understand and predict behavior (ours and others') Two components : affective (attribution of emotional mental states) and cognitive (attribution of cool mental states, such as thoughts and beliefs) (Premack & Woodruff, 1978; S. G. Shamay-Tsoory et al., 2007)	<u>Faux pas test</u> (Baron-Cohen et al., 1999; Bertoux et al., 2012) <u>Reading the mind in the eyes test</u> (Baron-Cohen et al., 2015) <u>TOM-15</u> (Desgranges et al., 2012) <u>Strange stories</u> (F. G. Happé, 1994) T.h.o.m.a.s (Theory of mind assessment Scale) (Bosco et al., 2009)
Emotional intelligence	Concept that links emotional and social competencies, by regrouping all abilities that allow an individual to process and understand their own and others' emotions. It allows to develop relationships by understanding others and acting appropriately (Bar-On, 2002; Salovey & Mayer, 1990)	EQI (Emotional Quotient Inventory): 133 items self-report questionnaire. One scale particularly refers to SC, the Interpersonal scale, which includes: empathy, social responsibility and interpersonal relationship. The three other scales refer to interpersonal level, stress management, adaptability and general mood (Bar-On, 2006)

**Neuropsychological tasks are underlined.*

Tableau 4 Key-words used for the electronic search - Manuscrit 1

Key-words used	
Social cognition	Pathological Gambling
mentaliz*	pathological gambling
mind reading	gambling disorder*
social cogniti*	problem gambling
social interaction	gambling addiction
social function*	excessive gambling
social brain	
affective cognition	
social knowledge	
social information	
processing	
emotion attribution	
attributional style	
theory of mind	
emotion processing	
attributional bias	
intention attribution	
empathy	
social perception	

Headings) terms relating to GD (n = 5) on the one hand, and to SC components (n = 17) on the other hand was used (see Table 4 for an exhaustive list).

Only publications in English or French between January 2013 and September 2018 were screened. Indeed, the article by Challet-Bouju et al. in 2017 investigated cognitive alterations, including SC, in pathological gambling and did not find any previous study for SC. Furthermore, social cognition is a recent field of interest in addiction, which justifies the focus on the last 5 years. This search was completed using a manual search by exploring the bibliographic reference lists from articles included to screen for potential eligible missing articles.

All articles dealing with SC explored with direct neuropsychological measures and with a link with GD were included. There was no exclusion criterion in regard to participants assessed to screen the largest number of articles possible, especially given the recent interest in SC for GD and the relatively few articles published (Challet-Bouju et al., 2017).

Tableau 5 Abstracts (n=305) and full-texts (n=17) excluded with reasons - Manuscrit 1

Reasons of exclusion of abstracts (n=305)	Number of articles excluded
the research assesses cognition without social aspect	67
the article focuses on epidemiology	52
the research does not focus on GD	61
the research does not use a direct neuropsychological measure of SC	71
the article presents a theoretical model	24
the article presents therapy interventions	16
the research focuses on social support and social environment	13
the year of the publication was before 2013	1
Reasons of exclusion of full-texts (n=17)	
the research assesses cognition without social aspect	3
the research does not use a direct neuropsychological measure of SC	12
the article presents a theoretical model	2

Study Selection and Data Extraction

All records were screened by the first author (EH). A preliminary assessment of the article titles from the initial electronic search was used to exclude all articles that were clearly off topic and resulted in a large number of exclusions. The remaining abstracts were screened for eligibility, and 18 articles were read fully.

Articles regarding cognitive assessment were read in order to not miss any social cognition evaluation, while a particular attention was given to methods of articles dealing with social support and quality of life of gamblers in order to check for the presence of neuropsychological tasks among questionnaires (see Table 5). The flowchart of the review process is presented in Fig. 4.

2.1.2. Results

As depicted in Fig. 4, 18 articles met our selection criterion, but only one article was finally retained (Kornreich et al., 2016) (see Table 5 for reasons of exclusion) and was focused on non-verbal emotion processing.

The only article selected was focused on non-verbal emotion processing and included outpatients seeking treatment for pathological gambling at the Brugman University Hospital (Kornreich et al., 2016). Diagnosis of pathological gambling was made based on DSM-IV criteria (score from 0 to 10, 5 criteria have to be present to be diagnosed), and patients were excluded if they had a history of psychiatric disorders. The Pathological Gambling group (PG) was composed of 22 male participants. The mean score on the DSM-IV scale also assessed the severity of PG (mean = 7.73, \pm 1.52). A control group of 22 males consisted of healthy participants matched on age and education level (C).

Non-verbal Emotion Assessment

The study by Kornreich et al. (2016) highlighted the deficits in emotion recognition in individuals with PG,

using the same methodology as those for substance-related addictions (Kornreich et al., 2012). Indeed, emotion processing was assessed using an experimental task on three modalities: musical, vocal, and facial. Regarding music modality, 56 piano excerpts were presented to participants (14 of each emotion for happiness, sadness, threat, and peacefulness). They had to judge the intensity of each emotion on a scale from 0 to 9. Concerning facial modality, stimuli consisted of 25 faces presented during 0.5 s and expressing 4 emotions (happiness, sadness, fear, and anger) and a neutral condition. Participants also had to rate the intensity of the four emotions for each picture on a scale from 0 to 9. Finally, regarding vocal modality, 35 affective non-verbal burst excerpts were used (Belin et al., 2008), 5 for each emotion (anger, happiness, surprise, disgust, sadness) and a neutral condition. Once again, participants had to rate the intensity of each of the 5 emotions on a scale from 0 to 9.

Outcomes consisted of the identification of the correct emotion, i.e., accuracy: if the emotion that was rated with the highest score was the one really depicted, then the response was scored correct. Regarding neutral stimuli, a response was correct if all emotions were scored as absent or of the same intensity. Intensity scores of each response were also recorded.

The intensity rating was only different for neutral conditions, with an overestimation of intensity in this modality. Finally, concerning facial modality, PG was significantly less accurate in identifying the targeted emotion, without any specific significant difference between emotions. The intensity rating was only different for the neutral condition in which PG significantly overestimated the intensity compared with controls.

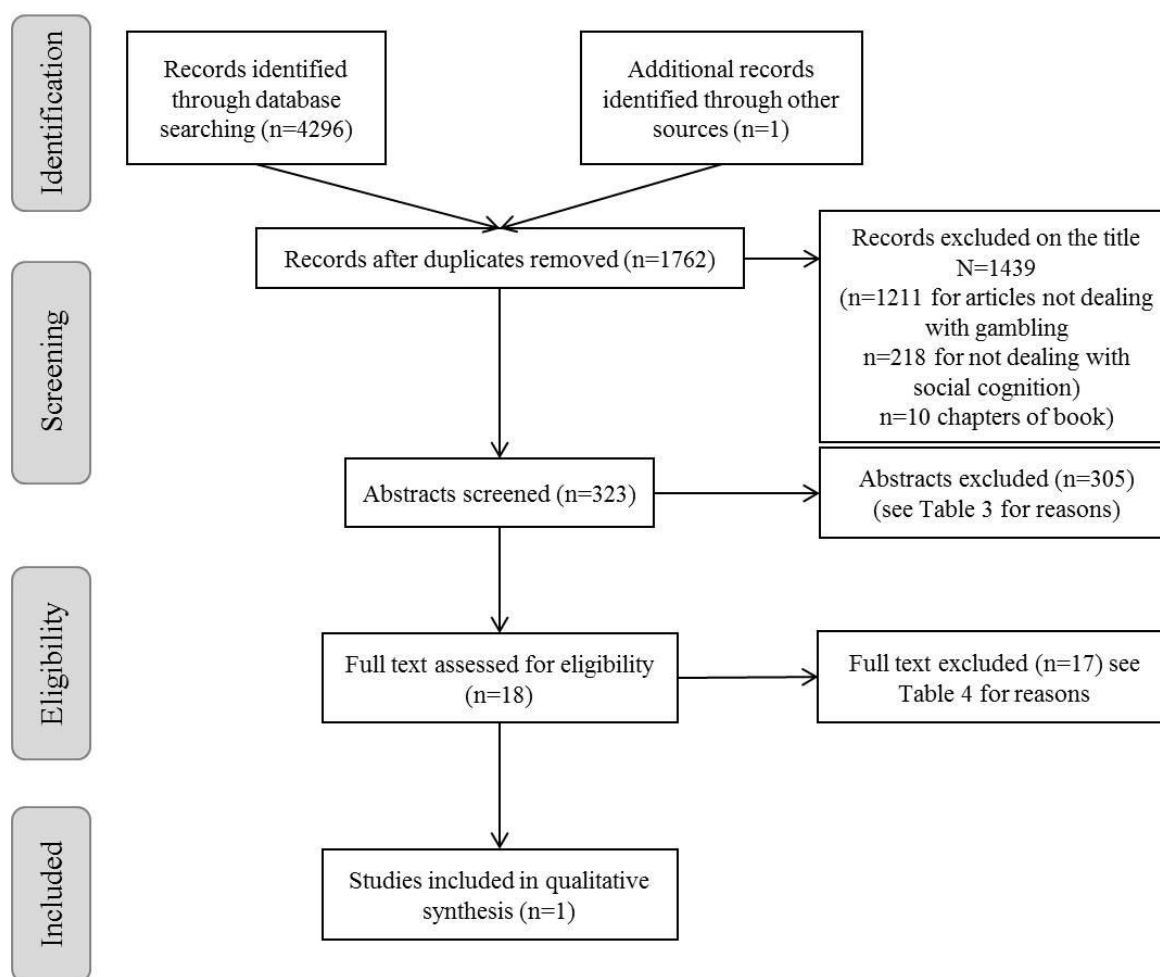


Figure 4 Flow diagram of records assessed – Manuscrit 1

Discussion and Limitations

This research highlighted the alteration of non-verbal emotion processing in pathological gamblers, which suggests impaired capacities for processing social cues. Pathological gamblers specifically presented difficulties in processing neutral cues. This profile has also been found in alcohol-dependent populations, suggesting either common deficits in processing social cues or attentional deficits known to be present in both populations (Goudriaan et al., 2004; Kornreich et al., 2012). Such difficulties in processing social cues could lead to social difficulties in daily life, although these were not assessed in the Kornreich study. Moreover, this research did not link the performance in emotion processing with personality traits that have been linked to SC, such as alexithymia. Indeed, this personality

dimension has been found to be higher for a large percent of gamblers (Bonnaire et al., 2009) and could impact SC performance (Goudriaan et al., 2004; Samur et al., 2013). Furthermore, because no women were assessed in this study, these results cannot be generalized for the GD population as a whole.

2.1.3. Discussion

SC and GD research

Only one study was identified as assessing SC in GD, using direct neuropsychological measures. This study (Kornreich et al., 2016) made direct observations of the social capacities of pathological gamblers concerning emotions processing. This research brings emotion recognition deficits to light regarding three different natures of emotional stimuli (faces, voices and music).

Nevertheless, no link was made with personality traits, specifically alexithymia, which is known to impact facial emotion recognition (Grynberg et al., 2012; Samur et al., 2013), neither with social functioning in daily life. Moreover, the sample only included males, making it difficult to generalize these results.

This study highlighted specific deficits in an addiction group of patients despite the absence of substance abuse. These findings support the idea that social cognitive impairment could be linked to addiction per se and may exist before the onset of gambling (Noël et al., 2013; Olievenstein, 1984), and not only be linked to the intrinsic neurotoxic effects of substances, even though many studies are required to confirm and extend these results.

Other Components of SC

Given that social functioning involves a large panel of abilities, it is also interesting to explore what have been done regarding the other components of SC, which have been assessed with self-reported measures (i.e., were not included in the systematic review).

Emotional Intelligence

Using the Emotional Quotient Inventory (Bar-On, 2002), two studies have shown a link between scores on the interpersonal scale and SOGS (South Oaks Gambling Screen (Lesieur & Blume, 1987)) scores in a population of non-problematic poker players and a population of special needs students (Parker et al., 2013; Schiavella et al., 2018). Those articles suggested that poor quality of interpersonal relationships may be found in populations of non-problematic gamblers, without the possibility of concluding the direction of the link of causality.

Empathy

The IRI questionnaire (M. Davis, 1980) has been used in a population of outpatients seeking treatment for GD. The results show that compared with a control group, the GD group showed lower global scores and scores

significantly lower on the perspective taking (PT) and fantasy (F) scales and higher on the personal distress (PD) scale (Tomei et al., 2017). This research seems to imply that the ability to infer and understand emotions in oneself and others may be altered in the GD population.

Theory of Mind

To our knowledge, no research has explored ToM competencies in GD. Nevertheless, it has been shown that people with alcohol use disorder present altered ToM abilities (Le Berre et al., 2017) and, more precisely, specific difficulties regarding affective ToM, while cognitive ToM abilities would be preserved (Maurage et al., 2016). Nevertheless, it is still unknown whether these deficits are linked to the consumption of neurotoxic substances or to addictive behavior.

Factors That Could Impact SC Assessment

Alexithymia

Alexithymia is a personality trait describing the tendency to have difficulties in processing emotions (Bibby & Ross, 2017; Sifneos et al., 1977). It is not a social cognitive function per se, but its level seems to impact the social functioning of the individuals, as well as their ability to identify emotional facial expressions (Grynberg et al., 2012). Therefore, it must be taken into account when social perception is assessed.

Gender and Social Cognitive Measurement

The study reviewed did not assess women, making the generalization of results difficult. Nevertheless, the incidence of women as pathological gamblers is lower than men, which could explain imbalanced groups and difficulties in comparing gender-stratified samples (Abbott et al., 2018), especially with low sample sizes. Regarding other social cognitive components, empathy appears to be higher in females than males (Gilet et al., 2013), and women tend to have higher scores on the EQ-I than men (Mandell & Pherwani, 2003). Parker et al. measured gender effects and confirmed this gender

difference on the EQ-I YV in a clinical population of adolescents. Thus, gender needs to be assessed and taken into account when measuring SC performance.

Summary of SC Assessment in GD and Perspectives for Future Research

Taken together, these studies may imply a global alteration of social cognitive abilities in the GD population, going from a perceptual level (difficulties in identifying emotional cues and one's own emotions) to the altered quality of interpersonal relationships.

Nevertheless, future studies using neuropsychological tasks may also need to take into account some specificity linked to the study of SC, such as the impact of personality traits or gender. It is also important to assess global intellectual functioning to control the impact of attention or executive deficits on SC performance (Merceron et al., 2011). It will also be essential to take into account the impact of GD severity, duration of gambling and other comorbidities, as these are known to influence SC performance in patients with substance use disorders (Bora & Zorlu, 2016).

To conclude, this research suggested the presence of SC deficits in an addictive disorder without the use of psychoactive substances, which may imply that such SC deficits are independent of intrinsic toxic effects of substance. However, it is still unclear whether these deficits pre-exist or appear after the onset of gambling. Only longitudinal studies would clarify this question and confirm whether cognitive performance does or does not decline with gambling practice. Eventually, further original research is needed to better understand SC in GD and to improve the understanding of the concept of addiction and to encourage the inclusion of social cognitive therapies in existing programs.

Clinical Implications: Cognitive Remediation Therapy and SC

Cognitive remediation is a therapy program aimed at improving cognitive functioning by training existing

abilities or work on the application of novel cognitive strategies to generalize improvements to daily life (Darmedru, 2017). This type of program is mainly proposed to improve cool functioning in diverse pathologies such as schizophrenia (Wykes et al., 2011), anorexia nervosa (Dahlgren & Rø, 2014), or traumatic brain injury (Bogdanova et al., 2016). Nevertheless, social cognitive training has also been developed to address SC deficits to enhance several aspects of SC by practicing and applying exercises to daily life (Kurtz et al., 2016). Several programs have been proposed, such as the RC2S (Cognitive Remediation of Social Cognition in Schizophrenia) (Peyroux & Franck, 2014) for patients with schizophrenia, the SCIT (Social Cognition and Interaction Training) (Penn et al., 2005) for schizophrenic or bipolar patients (Lahera et al., 2013), or the CREST (Cognitive Remediation and Emotion Skills Training) for anorexic patients (Tchanturia et al., 2015). Overall, it seems that social cognitive therapy improves social functioning (Kurtz et al., 2016; Kurtz & Richardson, 2012), neuropsychological tasks' performances assessing SC (emotion processing, ToM abilities) (Kurtz et al., 2016; Kurtz & Richardson, 2012; Lahera et al., 2013), as well as self-reported measures of alexithymia and anhedonia (Tchanturia et al., 2015). Regarding substance use disorder, existing programs target mainly cool functioning (Rezapour et al., 2016; Sofuoglu et al., 2013), as is the case for gaming disorder or GD, for which existing computerized cognitive remediation programs focus on cognitive bias toward the object of addiction (Boffo et al., 2017; Rabinovitz & Nagar, 2015). However, to our knowledge, no attempt at social cognitive therapy has been made to improve SC in GD patients. Nevertheless, it seems now important to add cognitive therapy that links cold and hot functioning as a complement to existing therapies (Berry et al., 2019; Horan & Green, 2019; Peña et al., 2016). Thus, the creation of this type of cognitive therapy focused on

both neurocognition and SC could improve global cognitive functioning and social functioning, which may participate in the maintenance of abstinence.

2.1.4. Conclusion

Only one published study has investigated SC with neuropsychological measures in pathological gamblers. Preliminary results are promising and tend to highlight a social cognitive impairment. However, more studies are needed to confirm and extend these results and to control certain factors, such as personality traits and gender. This is an important new avenue of research that may allow better characterization of the social cognitive profiles of gamblers and bolster the current literature. Furthermore, if studies confirm specific deficits of SC in GD, this may give alternative leads for social cognitive remediation therapies to integrate this solution with already known programs.

Compliance with Ethical Standards

Conflict of Interest Elodie Hurel, Nicolas Bukowski, and Emeline Eyzop declare that they have no conflict of interest. Marie Grall- Bronnec and Gaëlle Challet-Bouju declare that the endowment funds of the Nantes

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Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

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2.2.MANUSCRIT 2 : Revue systématique explorant l'évaluation de la cognition sociale dans les jeux vidéo (JV)

2.2.1. Résumé en français du manuscrit 2

Cette seconde revue de littérature avait pour but de décrire les connaissances actuelles sur les capacités de CS chez des joueurs de JV. L'objectif était de recenser toutes les recherches concernant la pratique du JV (pathologique ou non) et utilisant une mesure neuropsychologique de la CS. Cela permettait d'explorer le processus complet, de la répétition du comportement à l'addiction.

La recherche a été conduite jusqu'à janvier 2022 dans 3 bases de données (PubMed, PsycInfo et WebOfScience). Toutes les études avec une mesure de fréquence de jeu ou qui exposaient les participants plus d'une fois à un JV ont été incluses, ainsi que les études s'intéressant au JVP.

L'exploration systématique de la littérature a permis de trouver 39 études, évaluant le traitement des émotions faciales, l'empathie, la théorie de l'esprit (TdE), le comportement agressif et les compétences morales.

Parmi ces 39 études, 5 ont étudié les capacités de CS dans le JVP. Deux d'entre elles se sont intéressées au traitement inconscient cérébral des émotions faciales et suggéraient qu'un changement opérait sur le plan du traitement des émotions en présence de JVP. Cependant, ces deux études ont été menées avec des méthodologies trop différentes pour pouvoir être comparées (He et al., 2019; Peng et al., 2017). Sur le plan de la perception et l'attribution des rôles sociaux, les patients avec un diagnostic de JVP ont présenté les mêmes performances que des patients avec un trouble de l'usage de métamphétamine, et une performance inférieure à des sujets contrôles (Jiang et al., 2020). De plus, un score plus bas sur la tâche du *Reading the Mind in the Eyes Task* (RMET – tâche d'identification d'émotion en se basant uniquement sur les informations venant des yeux) a été liée à un plus haut niveau de sévérité de l'addiction aux JV (Aydm et al., 2020). Enfin, les patients présentant un diagnostic de JVP ont démontré des niveaux de coopération moindres en utilisant le paradigme du Chicken Game (CG) en comparaison de leurs amis joueurs contrôles. Enfin, dans cette même étude, un niveau de coopération plus élevé avec un joueur tout juste rencontré qu'avec un inconnu a été démontré, différence qui n'apparaissait pas chez les joueurs occasionnels (Su et al., 2018).

De manière intéressante, toutes les études s'intéressant aux JVP ont démontré des particularités de fonctionnement de la CS, voire des altérations. Un dernier article a été trouvé en dehors de la recherche systématique et sera ajouté au manuscrit après le processus de révision. Cet article suggérait que de plus basses capacités à reconnaître une émotion sur une version du RMET augmentait le risque de JVP chez des adolescents (Yavuz, 2018).

Tout comme lors de la première revue, il n'est pour l'instant pas possible de généraliser les résultats et de tenter de proposer un profil de CS des individus présentant un diagnostic de JVP. Cependant, les

différentes études menées donnent des pistes pour de futures recherches qui pourront explorer d'une part les composantes peu étudiées comme l'empathie, mais aussi tenter de répliquer les résultats obtenus en utilisant des tâches similaires.

Social cognition and gaming, what do neuropsychological data tell us? A systematic review of neuropsychological assessment of social cognition and gaming

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2.2.2. Abstract

Playing video games (VGs) has been found to be associated with cognitive changes and possibly psychosocial difficulties. Problematic gaming (PG) appears when the control over VGs is lost, which is now considered a behavioral addiction (BA) in the 11th version of the International Classification of Diseases under the term of gaming disorder. Models of understanding BAs include cognition as an essential factor in the development, maintenance and relapse of addiction. Nevertheless, some aspects of cognition remain underexplored, such as social cognition (SC), despite evidence of cognitive and social functioning alterations among patients displaying PG. This review aims to describe the current knowledge on SC among gamers gaming. This review focuses on both gaming (therefore, we did not include studies that did not assess frequency or did not expose participants to VGs more than once) and PG to explore the whole process from repeated exposure to addiction. Moreover, only assessments of SC with neuropsychological tasks were included, and patient-reported outcomes that could be biased by subjective self-report were not included. The search was through January 2022 in three databases (PubMed, PsycINFO, and Web of Science). The systematic search found 39 studies assessing facial emotion processing, empathy, theory of mind (ToM), social decision-making, aggressive behavior and moral competence. The research has generally shown mixed results, and a number of questions remain unanswered. Nevertheless, several studies showed cerebral changes when processing facial emotion that were linked with PG, while no link were obtained between VG exposure and empathy alterations. Links regarding cooperation patterns, ToM profile, moral competence and VG frequency were highlighted. Finally, there was great heterogeneity regarding the population assessed and the methods used.

Keywords Video games – Gaming disorder – Social cognition – Neuropsychology – Problematic gaming

2.2.3. Introduction

Gaming

Gaming is a modern leisure activity that includes video games (VG), such as massively multiplayer online role-playing games (MMORPGs), multiplayer online battle arenas (MOBAs), first-person shooters (FPS), or even sandbox games (games without planned scenarios) (Leouzon et al., 2019). Players can play for entertainment but also to deal with anxiety, depression or other psychological difficulties, even if the directionality of the link between motives/psychological difficulties and gaming is still poorly understood (Sunil et al., 2021). Playing VGs has been found to increase the activity of the sympathetic nervous system (Krarup & Krarup, 2020), lead to brain changes (Brilliant T et al., 2019) and enhance cognition such as top-down attention processes and spatial cognition (Bediou et al., 2018). Regarding the social sphere, it seems that time spent playing VGs is negatively linked with the quality of social relationships (Lo et al., 2005) but that psychological well-being and social functioning are positively linked with VG use in a population of heavy gamers (van den Eijnden et al., 2018). Gamers also display high online social capital (i.e., networking and its benefits resulting from it; Williams 2006) (Collins & Freeman, 2013).

Problematic gaming

When playing VG is associated with “*impaired control over gaming, increased priority given to gaming over other activities to the extent that gaming takes precedence over other interests and daily activities, and continuation or escalation of gaming despite the occurrence of negative consequences*”, this behavior corresponds to the definition of gaming disorder (GD), as proposed in the 11th version of the International Classification of Diseases (ICD-11) (World Health Organization, 2018). Problematic gaming (PG) is an umbrella term that refers to behaviors that correspond

to the definition of GD but also to other definitions that were used before the ICD-11 and that used other methods and frameworks to diagnose VG addiction (Schettler et al., 2022). The prevalence of PG is estimated to be between 0.7% and 27.5% of the general or gamer population, with more men affected (Mihara & Higuchi, 2017).

Models regarding the underlying processes of addictions are multifactorial, and these processes include cognitive functioning, among other factors (Brand et al., 2019; Brand, Snagowski, et al., 2016; Noël et al., 2013). Indeed, alterations in inhibitory abilities (Argyriou et al., 2017) and in frontostriatal and frontocingulate networks (Yao et al., 2017) have been highlighted in people with PG. Moreover, improvements in PG symptoms have been linked to improvements in cognitive functioning (Lim et al., 2016). In contrast, playing VG without PG has been linked with improved changes in cerebral structures and connectivity and an optimization of neuronal recruitment, especially for attention and visuospatial skills (Palas et al., 2017). Moreover, PG was found to negatively impact social relationships (Ryu et al., 2018). More specifically, individuals with PG display high online social capital, as was found for regular players, but low offline capital (Collins & Freeman, 2013). Additionally, psychological well-being and social functioning seemed to be negatively linked with the presence of PG (van den Eijnden et al., 2018) and even a predictor of it (Lemmens et al. 2011). The presence of PG has also been linked to familial (Hyun et al., 2015), emotional and behavioral problems (Frölich et al., 2016). Taken together, these studies suggest an alteration in social functioning in people with PG.

Social cognition – Definition

Thus, it seems that there is evidence for altered social functioning among individuals with PG, but these

effects are still not clear among individuals who play VG without PG. On the borderline between cognition and social functioning, social cognition (SC) includes all cognitive processes underlying social interactions, from the ability to detect and identify social cues to their interpretation to the creation of socially appropriate responses (Adolphs, 2001; Frith, 2008; Saxe, 2006). SC abilities also allow people to build their social norms that will serve as standards for future social interactions (Beer & Ochsner, 2006; Bertoux, 2016; Greifeneder et al., 2017). In association with these social abilities, the “social brain” theory postulates that the human brain is larger than that of the other species because of the complexity of our social world and specifically our ability to bond with others (Adolphs, 2009). The crucial role of SC in daily functioning has been evidenced in several psychiatric clinical populations, such as patients who suffer from schizophrenia (Brunet et al., 2003; Couture et al., 2006).

Components of social cognition

SC covers a large spectrum of cognitive functions and can range from the simplest tasks (e.g., recognizing an emotion on a face) to the most complex tasks (e.g., understanding irony or social decision-making). Several models exist regarding the number of components to include in the concept of SC (Fiske & Taylor, 2016; Green et al., 2015; F. Happé & Conway, 2016). For example, there is debate on whether or not the self should be included in this concept (F. Happé & Conway, 2016). In the same way, the inclusion of alexithymia (which reflects the inability to identify and describe emotions experienced by oneself or others (Etchepare and Prouteau 2018; Taylor et al. 1985)) within the spectrum of SC has been controversial. Several authors also proposed differentiating SC components based on more general characteristics, such as the level of processing (e.g., high or low levels or dual processing (Adolphs, 2009, 2010; Etchepare &

Prouteau, 2017; Frith & Frith, 2008)) or the nature of the stimuli involved (affective versus cognitive stimuli (Adolphs, 2010; Etchepare & Prouteau, 2017; McDonald, 2013; S. G. Shamay-Tsoory & Aharon-Peretz, 2007)).

In the following paragraphs, only components described in the systematic research are presented for the sake of clarity.

Social information/emotion processing, emotion attribution, and affective cognition

The study of social or emotion processing can occur at two levels: conscious (for example, asking the subject to identify the emotion or rate its intensity) or unconscious (in this case, the participant has to attend to another task while faces are presented). Facial emotion processing seems to be underpinned by two networks: the ventral network deals with static stimuli and allows for linking the stimuli with information such as the identity of the face, while the dorsal network deals with dynamic stimuli (Duchaine & Yovel, 2015). The ability to process emotions and make assumptions about them can also be called affective cognition (Ong et al., 2015).

Empathy

Regarding the study of the concept of *empathy*, which is, broadly, the ability to feel what another person is feeling and understanding him or her (Lockwood, 2016), several models can be found in the literature. For example, one model postulates that there are two components in this concept: the first component involves the ability to understand motives and thoughts from another person (i.e., *cognitive empathy*), while the second component involves the ability to experience the feelings of another person (i.e., *emotional empathy*) (S. Shamay-Tsoory et al., 2009). Another model separates empathy into two different components: the first component, called *personal distress*, is self-oriented

and reflects the tendency to try to alleviate one's pain; the second component, called *compassion* (or *empathic concern*), involves the ability to feel sympathy for others (Singer & Klimecki, 2014). The function of empathy, also called vicarious experiences, seems to be underpinned by the anterior cingulate cortex and the anterior insula (Lockwood, 2016; Singer & Klimecki, 2014).

Theory of mind, attribution style/bias, and intention attribution

Another component that can sometimes be considered similar to affective empathy (Decety & Lamm, 2006; Lockwood, 2016) is *theory of mind* (ToM), also called mentalizing, mind reading or cognitive perspective (Singer & Klimecki, 2014). ToM is the ability to infer mental states (*cognitive ToM*) or emotional states (*affective ToM*) of another person (Shamay-Tsoory and Aharon-Peretz 2007) to understand and predict his or her behavior (Premack & Woodruff, 1978). ToM seems to be underpinned by a network including at least the medial prefrontal cortex (mPFC) and bilateral temporoparietal junctions (F. Happé & Conway, 2016; Schurz et al., 2014). Attribution style, defined as “*how people deduce causal relationships and characteristics of other persons in the environment*” (Fiske & Taylor, 2016), can also be linked to the concept of ToM and allows the observation of hostile attribution bias, as can be found in individuals with schizophrenia (Buck et al., 2020).

Social decision-making

On another level of reasoning, *social decision-making* is the ability to make a decision that will affect ourselves and another person, for which the outcome depends on another person's and our behaviors. This function seems to be underpinned by the prefrontal cortex but also by the amygdala and insula, which handle affective biases that impact decision-making (Rilling & Sanfey, 2011).

Aggressive behavior

Aggressive behavior is the administration of an unpleasant stimulus to another person (S. P. Taylor, 1967). Cognitive activity associated with this behavior seems to be linked with the dorsal part of the mPFC, while the affective component (i.e., compassion during punishment) seems to be handled by the ventral part of the mPFC (Lotze et al., 2007).

Moral decision-making

Another component of SC presented in this article is moral decision-making. This ability refers to (i) a particular predilection toward moral orientations (affective component), (ii) the ability to make decisions regarding moral dilemmas based on those moral aspects (cognitive component, also called *moral competence*) and (iii) the fact that decision-making is not dependent on the issues in the particular situation (Jung et al., 2016; Lind, 2008). This ability is underpinned by emotional and cognitive processes that come into play in decision-making. For example, a higher level of moral competence has been linked to higher functional connectivity between the amygdala and the ventral mPFC and lower connectivity between the amygdala and frontoparietal control network (Jung et al., 2016).

Social knowledge

Social knowledge refers to all the information stored in memory that can be used to infer mental states. This information can be general (norms about how to behave in certain situations or places) or specific to the person with whom the interaction takes place (for example, information about the history of the person) (Achim et al., 2013; Langdon et al., 2014).

Social cognition and gaming

The aim of this review is to describe the current knowledge linking SC and gaming. Indeed, it seems that the practice of engaging with VGs, and even more PG, can impact both cognitive abilities and social

functioning and perhaps SC, but it also seems that poor cognitive functioning, specifically SC, may lead to increased time spent playing and even PG. As SC is on the border between cognition and social functioning, it is legitimate to explore the literature on SC in gaming to highlight the social cognitive profiles of gamers with or without PG and to identify what SC competencies are involved.

2.2.4. Method

Search strategy

The search strategy was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) recommendations (Moher et al., 2009). The search was conducted through January 2022. No registration was made, and no protocol was prepared.

We planned to register the protocol of this literature review upstream on the Prospero registry, but the registration was not accepted because the data explored were not considered related to a health condition (Moher et al., 2014). The search was performed in three databases (PubMed, PsycINFO, and Web of Science). Key words regarding SC and VG were crossed (see Table 6) resulting in the following search: ("video game" OR "video games" OR videogame OR videogames OR game OR games OR gaming OR gamer) AND (mentalization OR mentalizing OR mentalising OR "mind reading" OR "social cogniti*" OR "social interaction" OR "social function*" OR "social brain" OR "social decision" OR "social perception" OR "affective cognition" OR "social knowledge" OR "social information processing" OR "emotion attribution" OR "attributional style" OR "theory of mind" OR "emotion processing" OR "attribution bias" OR "intention attribution" OR empathy). The search focused on articles written in French or English.

Tableau 6 Keywords used in the database search – Manuscrit 2

Gaming keywords	Social cognition keywords
Video game(s)/videogame(s)	Social function(ing)
Gaming	Social cognition/social cognitive
Game(s)	Social interaction
	Social brain
	Social perception
	Social information processing
	Affective cognition
	Emotion attribution
	Emotion processing
	Empathy
	Mentalization/mentalising/mentalizing
	Mind reading
	Attributional style
	Theory of mind
	Attribution bias
	Intention attribution
	Social decision
	Social knowledge

Inclusion and noninclusion criteria

This systematic review focused on both gaming (therefore, we did not include studies that did not assess frequency or did not expose participants to VGs more than once) and PG to explore the whole process from repeated exposure to addiction.

Short-term exposure to VGs was not included in the framework of this review because changes in cognitive functioning need the repetition of an action (that can be harmful or therapeutic) and thus need time to appear

Tableau 7 Reasons for exclusion at each step of the screening – Manuscrit 2

Reasons for exclusion based on titles (n=8947)	
Is not an original research article	282
Videogames (VG) is used as a tool or a serious game	2664
Is not about gaming	5618
Is not about cognition	384
Reasons for exclusion based on abstracts – first reading (n=948)	
Is not an experimental research article	88
Is not written in English or French	1
Is not about gaming	56
Game is used as a tool, or a serious game	55
Is not focused on cognition	572
Frequency of gaming is not assessed	19
Is not focused on social cognition	157
Reasons for exclusion based on abstracts – second reading (n=119)	
Is not an experimental research article	8
Is not written in English or French	2
Game is used as a tool or a serious game	16
Is not about gaming	5
Is not focused on social cognition	22
Is not focused on cognition	66
Reasons for exclusion based on methods (n=185)	
Is not an experimental research article	8
Is not written in English or French	3
Game is used as a tool or a serious game	2
Is not about gaming	3
Is not focused on cognition	93
Is not focused on social cognition	76
Reasons for exclusion based on full texts (n=110)	
Game is used as a tool, or a serious game	2
Frequency of gaming is not assessed	32
Is not an experimental research article	13
Does not use social cognition neuropsychological task	38
Frequency of gaming is assessed, but is not used to study its impact on social cognition (SC) performance	18
Only short term exposition to VG is assessed	7

Moreover, only assessments of SC (with a social object) based on neuropsychological task performance (i.e., performance-based tasks objectively linking behavior and brain (Casaletto & Heaton, 2017)) were included in this review, and studies using patient-reported outcomes (which are subjective assessments made by the patient (Rothman et al., 2007)) were not included. Indeed, self-reported data are subjective information, and they do not allow an evaluation of the quality of cognition.

Articles were included if (i) they evaluated participants' frequency of gaming OR the effect of playing VGs more than once OR patients with PG AND explored its impact; (ii) a neuropsychological task of SC was used.

Study selection

After exclusion of duplicates, each title was screened by the first author and excluded if it was clearly not within the scope of the review (i.e., all articles not considering VG as a leisure activity or not assessing cognition). This selection process resulted in a large sample of abstracts that were screened twice. The first reading by the first author excluded abstracts that were clearly off-topic. The second selection of abstracts was performed using Abstrackr software (Wallace et al., 2012) by the first and fifth authors.

This software can be used to gain time by screening titles and abstracts based on machine learning that classify titles as relevant or not (Rathbone et al., 2015). We only used it as a collaborative tool that was accessible online.

Because of the lack of information in abstracts, a large number of articles were kept during this abstract screening step. The methods of these articles were screened by the first and fifth authors to ensure that we did not miss any study that could have included neuropsychological SC tasks. Therefore, we chose to read the methods of all articles dealing with cognition in gaming, even with no apparent SC assessment and/or apparent exclusive use of self-rated questionnaires. Finally, studies were fully read and included in

accordance with the inclusion criteria. To complete the database search, the first author performed a manual search and screening of the bibliographic references of the studies included and from a recently published meta-analysis regarding gaming and social outcomes (Greitemeyer & Mügge, 2014).

Data extraction

Each full text that was considered eligible was read by the first author. Information about the population, measures of VG use or PG, cognitive assessment of SC, and main results exploring the effect of VG are presented in Table 8.

2.2.5. Results

The systematic search resulted in the selection of 39 studies. Research included in the previously published meta-analysis led to the screening of 52 additional records, from which 34 were screened based on their abstract, 15 were then screened based on their full text, and 3 were finally included. All numbers and reasons for exclusion at each step are included in Table 7 and Figure 5. Moreover, all references from articles included from the systematic review and the exploration of the previously published meta-analyses (n=23) were also screened, and four articles were included from these lists.

To facilitate understanding, the articles are presented according to the various components of SC assessed (i.e., facial emotion processing, empathy, ToM/bias of attribution, social decision-making, aggressive behavior, and moral competence) and ranked from the most recent to the oldest in Table 8. Additionally, for each SC component, studies are separated regarding their methodology (comparing groups or correlation studies) to highlight the power of the studies.

Facial/social emotion processing

Ten articles explored the link between exposure to VGs and social emotion processing.

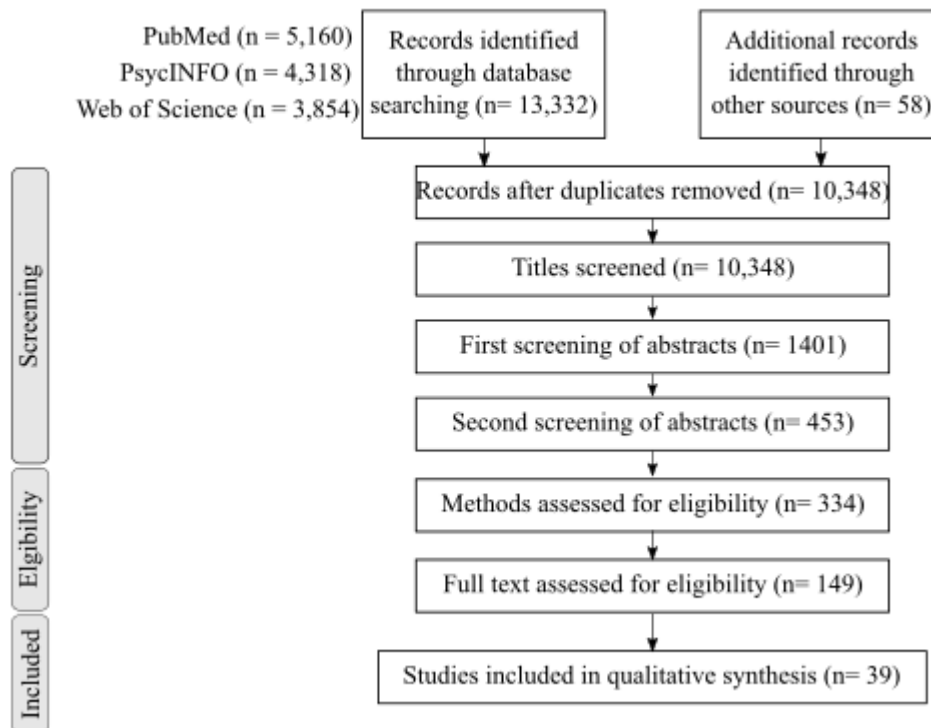


Figure 5 Flowchart of the systematic review - Manuscrit 2

Cerebral processing was assessed in some of these studies. For example, researchers showed that when comparing two groups of players of violent VGs (frequent or not) on a Stop Signal Task (SST) while recording event-related potentials (ERPs), the unconscious processing of emotional facial stimuli was different for happy faces, with smaller amplitudes recorded from the frequent players (Stockdale et al., 2017). Regarding the detection of emotional stimuli, research has shown that after 10 hours of training on VGs (action VG or nonaction VG), differences in reaction times between the nonaction VG group and control group were already observable, and the type of VG played had a differential impact on cerebral processing (Bailey & West, 2013). Finally, five studies assessed the ability to process and discriminate facial emotions. Studies have shown that years of experience with VGs could positively impact abilities in emotion identification and that the number of hours played may negatively impact joy identification (Miguel et al., 2017). Exposure to VGs may also be linked with worse

abilities to identify negative emotions (Miedzobrodzka, Buczny, et al., 2021). Moreover, VG players seemed better at recognizing fear but worse at recognizing disgust than controls (Diaz et al., 2015). Additionally, a study found that professional e-sport players and controls displayed the same capacity of judging whether or not emotions were either identical, which was lower than the capacity of professional baseball players. In the same study, the authors showed that the elite e-sport players displayed faster reaction times than the rest of the group (Kang et al., 2020). Finally, no difference appeared when comparing VG players and non-VG players on a task of identifying morphing emotions (Pichon et al., 2021).

When assessing participants with PG compared to controls with tasks assessing unconscious processing of faces (Peng et al., 2017) and cartoons and faces (He et al. 2019), studies have shown differences in ERPs. For example, one study showed a reduction in the N170 component, which reflects the detection of a face (Schweinberger & Neumann, 2016), in the PG group

when processing neutral faces compared to happy faces, while there was no reduction in the control group. Another study showed a larger peak for cartoons compared to human faces only in the right hemisphere in the PG group, while this difference was present in both hemispheres in the control group, suggesting specific processing of facial stimuli in those with PG (see Table 8 for details). Moreover, when comparing PG patients to controls or to patients with methamphetamine use disorder on a task of social perception, both patient groups displayed lower scores than the control group (Jiang et al., 2020).

Empathy

Five studies assessed empathy abilities in a population of gamers. No differences between groups were found regarding empathy abilities, using an empathy-for-pain task with emotional stimuli (photography or drawings) using fMRI, by comparing frequent gamers to nonfrequent gamers (Gao et al., 2017; Szyck et al., 2017), or after an eight-week period of exposure to VGs (Kühn et al., 2018). However, comparing a group of individuals with low exposure to violent VGs to a group of individuals with a high level of exposure, a desensitization to painful stimuli (similar EEG results for painful and nonpainful stimuli) was found only for the high-exposure group (Miedzobrodzka, van Hooff, et al., 2021). Finally, no link between violent VG exposure and a scale measuring empathy for a rape victim was found (Ferguson & Colwell, 2020).

No study was found on PG and empathy.

Theory of mind/bias of attribution

Twelve studies explored ToM abilities in relation to VG practice. Among them, eight studies explored ToM by means of stories. Studies with young children showed no link between the rate of aggressive intent in ambiguous stories and exposure to VGs (Ferguson & Wang, 2019) but found a link between higher exposure

to violent VGs and lower scores on vignettes in which participants had to tell what was going on next but also how they would have reacted in stories that were designed to induce empathy (Funk et al. 2003). Studies with adolescents showed a negative correlation between exposure to prosocial VGs and hostile attribution bias, as well as a positive correlation between hostile attribution bias and exposure to violent VGs (Gentile et al. 2009). Moreover, one study did not find a relationship between exposure to VGs and attribution bias (Krahé & Möller, 2004). Finally, attribution bias was identified as a mediator between exposure to VGs and behavior (Möller & Krahé, 2009; Zhen et al., 2011). Studies with adults showed either a positive correlation between exposure to VGs and levels of aggressive thoughts, feelings and behaviors attributed to characters in ambiguous stories (Eastin & Griffiths, 2009) or no link between attribution bias and frequent exposure to FPS (Hopp et al., 2018).

Using the Reading the Mind in the Eyes Task (RMET), no link between violent VGs and RMET scores was found in participants with eight weeks of VG practice (Kühn et al., 2019). With the same task, a positive link between the ability to infer correct mental states and better VG performance scores was highlighted (Bonny et al., 2020).

Finally, in a study of children that used six different tasks to assess ToM, gaming time negatively predicted boys' scores on the ToM task after a year (MacGowan & Schmidt, 2021).

Regarding PG, a higher number of symptoms of PG was linked with poorer scores on the RMET task (Aydın et al., 2020).

Social decision-making

One study assessed social decision-making in undergraduates in association with their experience with VGs. This study showed that experienced gamers

tended to be less cooperative than nonexperienced gamers (Jin & Li, 2017).

One study assessed social decision-making in PG with the chicken game paradigm. The chicken game is an economic game in which two players have to simultaneously make a decision. In this paradigm, not cooperating is the riskiest option with the highest gain. PG patients tended to take riskier options and cooperate less than controls (Su et al., 2018). Moreover, PG patients displayed comparable levels of cooperative behavior when playing either with a friend or a game mate (who they just met in the framework of the chicken game task), in contrast to controls who were more cooperative only with their friend.

Aggressive behavior

Nine studies explored the link between the frequency of playing VGs and the competitive reaction task (CRT), which is designed to explore aggressive behavior. In this task, participants are instructed to react as fast as possible to a noise stimulus. The loser (i.e., the slowest individual) is punished by a blast of noise presentation, for which the duration and intensity are decided by the winner. In most experiments, tasks are programmed to provide half of the victories to the participant, and the intensity and duration of the blast of noise are measures of aggressive behavior (Chester and Lasko 2019; Taylor 1967). These studies have shown mixed results. Indeed, a higher level of exposure to violent VGs has been linked to a more aggressive response pattern (Bartholow et al., 2005, 2006) and specific EEG responses in reaction to violent pictures (Bartholow et al., 2006). Interestingly, in this last study, the authors separated the effect of content (violent or not) from the frequency of play, and the link with aggressive behavior was significant only in relation to the content. Furthermore, action VG players displayed a higher level of aggression than nonplayers (Pichon et al., 2021). Moreover, a tendency to display higher to aggressive

levels in the CRT was found after playing a violent VG regardless of previous gaming experience (Engelhardt et al., 2011). Nevertheless, among a population of regular gamers, this link was found only in the group that played a violent VG and not in the group that played a neutral game (Arriaga et al., 2011). Finally, no links were found in four other studies (Deville et al., 2021; Ferguson et al., 2008; Ferguson & Rueda, 2010; MacGowan & Schmidt, 2021).

Another type of measure was used in the last study: participants were asked to rate the profile (if they were competent, courteous, deserving of financial support worthy of being recruited) of a volunteer to a paid position in the laboratory. Lower ratings were considered a measure of aggressive behavior. No link was found between exposure to VGs and level of aggressive behavior (Tamborini et al., 2004).

No study was found on PG and aggressive behavior.

Moral competence

Two studies assessed this component in a population of students and showed a positive link between the amount of exposure to VGs and moral reasoning during VG play (Krcmar & Cingel, 2016). Moreover, exposure to VGs was also correlated with moral competence (Sofia & Klimenko, 2019).

No study was found on PG and moral competence.

Tableau 8 Description of articles found in the systematic search – Manuscrit 2

First author, year of publication	Population assessed	Characteristics of groups	Gaming information	Measure of SC	Main results
Facial emotion processing					
<i>Comparison between groups</i>					
Pichon, 2021	Study 1: Participants that answered local adds. Study 2: University students.	Study 1: 47 VG players (AVGP): mean age=22.3, sd=4.3). 50 non VG players (NVGP): mean age=24.2, sd=5.1. Study 2: 27 AVGPs (mean age=22.81, sd=2.69), 27 NVGP (mean age=22.96, sd=3.66).	AVGP: played 5 hours per week of FPS, and 1 to 5 hours per week of another VG. NVGP : played at most 5 hours per week across all games possible, and 1 hour at most of each possible VG.	Study 1: Face stimuli: morphing expression with a sequence of 15 steps, going from sad to angry and from pain to happy; and from neutral to pain, happy, fear or sad in the session 2. Participants had to identify the emotion displayed. Study 2: facial animation with 3 facial muscles randomly chosen among 42 possible action muscles. After each animation, participants had to categorize the emotion displayed among 7 possible choices (happy, sad, angry, fearful, surprise, disgust or other), and had to rate the intensity.	Study 1: no difference between groups for emotional identification for both sessions. Study 2: no group effect was found on the discrimination task.
Kang, 2020	Professionals gamers (esport players group : EPG) and professional baseball players (pro-baseball group : PBG)	EPG: n=55, mean age=21.3, sd=1.4, PBG: n=57, mean age=21.3, sd=1.4. Control group (CG) from the general population matched on sex, n = 60, mean age=21.3, sd=1.5.	EPG : among them, an elite group (n=12) that participate in 80% of the games of the season, PBG : among them, an elite group that attended 144 major league games on 144 or that had 446 plate appearances.	Emotion Perception test: 108 trials, 2 to 8 faces displayed on the screen. Participants had to indicate if all faces presented displayed the same emotion or not.	The PBG group displayed faster reaction times than the EPG and the CG. The elite group of the EPG displayed faster reaction times on the emotion perception test compared to the rest of the EPG group.

Jiang, 2020	Patients from a mental health facility and citizens of Wuxi	<p>Internet Gaming Disorder group (IGD): n=30, mean age=22, sd=5, 53.3% male.</p> <p>Methamphetamine group (MD): n=30, mean age=22, sd=6, 43.3% male. Normal control group (NC): n=30, mean age = 22, sd=6, 50% males.</p>	<p>IGD group: had to meet the IGD criteria of the DSM-5, MD group: had to meet the criteria of MD dependence according to the DSM5, had cumulate MD use of over 50 mg, less than 2 hours per day on the internet. NC group: no smokers, no diagnosis of alcohol use disorder or substance dependence, less than 2 hours per day on the internet.</p> <p>PG group: IAT score ≥ 80, IGAS ≥ 7, game mainly played is "Strike of King", and the clinical interview led by two psychiatrists concluded to PG diagnosis. Control group: IAT score ≤ 40, IGAS score ≤ 3, with a preferred game "Strike of Kings".</p>	<p>IPT-15 (Interpersonal Perception Task), used to measure social perception. It consisted of 20 minutes' video of 15 scenes including one to four roles. 5 social roles were possible (kinship, intimacy, deception, competition, status). Participants had to identify the correct role displayed in the scene.</p>	<p>IGD group score on the IPT-15 is comparable to the score of the MD group. Both groups scored lower compared to the control group on this task.</p>
He, 2019	Undergraduates students from Wuhan University	<p>PG group: n=15, mean age=20.97, SD=1.65. Control group: n=15, mean age=21.02, SD=1.70</p>	<p>Frequent players of graphical violent game criterion: playing at least 30 hours of VG per week, 2 of 3 VG played have to be violent. Group of infrequent players of graphically violent games must play no more than 5 hours a week, with 2 of the 3 games mainly played not classified as violent.</p>	<p>Oddball paradigm: participants answered to the change in size of the fixation cross while pictures of faces (humans or from the VG "Strike of King") appear and disappear. Participants were to ignore the faces. Two blocs were displayed, one with humans as standard stimuli and cartoons as deviant (with a ratio of 8:2), and the other one was reversed. EEG was continually recorded.</p>	<p>Analyses showed that, for cartoon faces, the PG displayed enhanced P100, P200 and MMN components, and an absence of left dominance of the N170 component. The PG group also displayed an advantage when processing cartoons</p>
Stockdale, 2017	University students	<p>Frequent players of violent graphical game: n=30.</p> <p>Infrequent players of graphically violent games: n=31. Mean age=20.68, SD=.21.</p>	<p>Stop signal task (SST): involved two emotions that could be displayed by faces: happy or afraid. Participants were asked to press the button to choose if the face presented is a woman or a man and not press if a stripped box around the stimulus appears—difficulty increases when participants produce correct answers. EEG was continually recorded.</p>	<p>SST results: no significant difference was found between groups. For the P100/N200 and P300 components, smaller amplitude in frequent players than infrequent players, and specifically for happy faces were evidenced. For the N170 component, non frequent players had faster latencies for afraid facial expressions than for happy facial expressions. Frequent players had faster latencies for happy expressions than for afraid ones in go</p>	<p>SST results: no significant difference was found between groups. For the P100/N200 and P300 components, smaller amplitude in frequent players than infrequent players, and specifically for happy faces were evidenced. For the N170 component, non frequent players had faster latencies for afraid facial expressions than for happy facial expressions. Frequent players had faster latencies for happy expressions than for afraid ones in go</p>

Peng, 2017

Local university students of in Shenzhen, China

PG group: n=16, mean age=20.75, SD=0.36. Control group (CG): n=16, mean age=20.24, SD=0.4.

PG group was composed of participants with a score ≥ 40 on the IAT, spending at least 4 hours a day and 30 hours a week on Internet gaming, and with less than 40 points on the Zhung Self-Rating Depression Scale nor the Zhung Self-Rating Anxiety Scale

Faces (neutral or happy/sad depending on the block) were displayed on the screen with a backward mask paradigm permitting the observation of unconscious processing. Participants had to indicate if the stimuli seen is an emotional or a neutral stimulus. EEG was recorded.

trials. In stop trials, frequent player group displayed lower mean amplitudes than non frequent players.

The CG was faster than the PG group on the sad block. Reduced amplitudes of the N170 component (reflecting facial processing) were observed for the PG group when processing neutral faces compared to happy ones, while CG did not show any difference in this situation. No other difference between groups was found.

Bailey, 2013

Students from Iowa State University

Non-contact group: n=9 (mean age=24.22, SD=8.43). Action-group: n=10 (mean age=20.40, SD=2.01). Non-action=9 (mean age=21.77, SD=4.02)

Subjects reported playing 0 hours of gaming per week and weekend. The non-action group played Tetris for 1 hour each day for ten days, while the action group played an action game for the same amount of time. The noncontact group did not play. The three groups were assessed twice, spaced by ten days.

The emotion search task was used with matrices with 9 faces presented to participants. They had to decide whether there was an emotional face among the neutral (anger or happiness can be depicted). This task was performed with EEG recording.

Amelioration of reaction times was found when comparing non-contact group to the non-action group, with a diminution of difference in reaction time when the target was present or not for the non-action group. Effects on cerebral processing were different between gaming groups, with, for example, a diminution of attention for happy faces in the action group (shorter latencies on P3 in the action group between pre and post-tests, while the non-action group showed differences in the processing of targets (difference with the electrode P3 on the right hemisphere, with a greater amplitude between pre and posttests). An analysis of latent variables was also conducted, see the original article for details.

Correlation studies

Miedzobrodzka, 2021	High school students (study 1) and Students from the University (study 2)	Study 1: N=69, mean age=17.06, sd=0.69. Study 2: N=151, mean age=26.68, sd=6.93).	Both studies : VVG was computed thanks to the rating of the frequency and violent content of VG.	Both studies: the Facial Expressions Matching Test, measured the ability to recognize negative emotions from facial expressions (disgust, fear, anger, sadness). Four faces were displayed, one was in the center and his or her emotion had to be matched with one of the three faces on the bottom.	This research showed a negative relationship between VVG exposure and accuracy in the recognition of negative facial expressions for adolescents and adults.
Miguel, 2017	Participants recruited via online systems	N=164, mean age=18.93, SD=6.36, min= 14, max=59, 123 females.	A game preference questionnaire was created asking about the frequency, the type of game, who they play with, etc.	Computerized test of primary emotions perception (PEP) included 38 soundless videos in which actors display emotions that the participant had to identify.	A positive correlation between the time spent playing VG (in years) and the general perception of emotion were found. Moreover, a negative correlation between playing hours and attribution of joy was found in which the more you played, the less you attributed joy. A correlation between the frequency of meeting people to play and general emotion perception was highlighted, in which the more you met, the better the emotion identification.
Diaz, 2015	Undergraduates students from the University of Calgary	N=152, 73 males, mean age=20.45, SD=3.12.	Prescreening selected participants playing 0 hours a day, or at least 2 hours a day of VVG (realistic or fantasy, according to Entertainment Software Rating Board)	Facial emotion identification task was used in which participants had to decide the emotion displayed by the face presented or the gender in the control condition. The intensity of emotion was low, medium or high.	No overall effect of group was found. VVG players were more accurate and faster, in identifying fearful faces than non-gamers. Non-gamers were more accurate for identifying disgust faces than those who played VVG.

Empathy

Comparison between groups

Kühn, 2018	General community using flyers and advertising on the Internet	N=90, mean age=28, SD=7.3, range = 18-45, 48 females. 3 groups: VVG group: n=26, mean age=27, SD=6.1, 14 females. Active game control group: n=24, mean age=26.1, SD=6.9, 13 females). Passive control group: n=30, mean age=30.8, SD=8.3, 13 females.	No VG use in the past six months. Training consisted of playing VG for eight weeks for approximately 30 minutes a day. The VVG group played Grand Theft Auto, the active control group played the Sims, and the passive control group did not play. Assessments took place before the gaming training (baseline), right after the two months of training (T1) and then two months later (T2)	Twenty-eight photographs were shown in the fMRI, all of them contained hands with tools, and half of them were hurtful.	No desensitization for pain (diminution of reaction to presentation of violent stimulus) was found.
Szyck, 2017		Only males. VVG group: n=15, mean age=22.8, SD=4.3 years. Control group: n=15, mean age=22.1, SD=3.0.	VVG group was composed of participants who played first-person shooter VG for at least four years for two hours daily. The control group reported no experience of playing VG.	Drawings with black lines were presented, which were emotionally charged or not, and with a social situation or not. Drawings were presented for 4 seconds in the fMRI, and participants were asked to watch carefully and imagine how they would feel in this situation.	No differences between groups were found.
Gao, 2017	Southwest University, China	20 students from the 25th percentile and 20 students from the 75th percentile comprised the high and low exposure groups. Range age was 18-27 years, mean age=21. 17, SD=0.065. VG	Two hundred undergraduates completed the Anderson and Dill video-game questionnaire in which VG played were listed and then rated regarding their amount of violence and the frequency played. A score of VG exposure was then calculated.	In the fMRI, painful or non-painful pictures of hands were displayed. Participants were asked to concentrate and try to experience what the persons whose body parts are shown in the picture was experiencing.	No difference between groups was found.

group: n=18. Non-gaming group, n=17.

Correlation studies

Ferguson, 2020

Mails and social media diffusion

125 participants (57 men), mean age=26, sd=11.2.

Participants cited their three favorite VG and rate the frequency of play of each. Each VG response was rated in term of violence and sexualized content.

A vignette of rape is presented to participants, and a scale of empathy toward the victim is used to assess feelings (Gabbiadini, 2016).

No effect of VVG and sexualized VG use on the scale of empathy toward the rape victim was found.

Miedzobrodzka, 2021

University students

N=58 (100% male), mean age=22.41, sd=3.42, right handed

VVGE was measured using the name of the three favorite games, the time spent on these games and official violent content ratings.

Pain judgement task: in this task, participants watched pictures of hands in a situation of painfulness or non painfulness while EEG was recorded. Participants had to categorize each picture as painful or not. Intensity of pain was rated within a second block.

P3 (particular sensible to aversive stimuli) and P625 are reflective of top down response to painful pictures. P3: no difference was found between painful and non painful pictures in the group of high VVGE, contrary to the group with low VVGE, suggesting desensitization. P625 : a difference between painful and non painful pictures with higher amplitudes for painful pictures were found for both groups.

Theory of mind - Bias of attribution

Comparison between groups

Kühn, 2019

Participants from the general population

VVG group: n=25, mean age=26.6 years, SD=6.0, 14 females. Active control group: n=24, mean age=25.8 years, SD=6.8, 12 females. Control group: n=28, mean

The VVG group played Grand Theft Auto 5 for eight weeks, 30 minutes a day, while the active control group played Sims 3 for 8 weeks and 30 minutes a day. The control group was not given a game to play.

Reading the Mind in the Eyes task (attribution of complex emotions based on photography of eyes) was used, among several other non-SC tasks.

No effects of the VVG were was shown.

age=30.9 years,
SD=8.4, 12 females.

Correlation studies

Bonny, 2020	Players of MOBA (Dota 2) going to a tournament	N=335 (31 females, 311 male), mean age=23.418 years, sd=4.075. Participants provided a	Steam account for statistics data. Experience was reflected by the number of match completed. Player performance is the match making rating (MMR, calculated by the algorithm of the platform and not available) and Win Loss Ratio (WLR). Several measures of gaming experience were made (T0 being the tournament, T2 at 3 months and T3 at 4 months) VVGE was measured using the name of the three favorite games, the time spent on these games and official violent content ratings.	Reading the mind in the Eyes (RME) is a measure of ToM. Only pictures of eyes were available to decide which emotion among four was the correct one. Economic cooperation task: participants had to choose to cooperate or not with strangers for a fictional company. If both cooperate, the profit was higher than if both defect. If only one decide to cooperate, this company had an economic disadvantage compared to the company that defected.	RME accuracy was found a significant predictor of MMR. Better RME scores had a greater impact on the performance improvement of party (playing with familiar people) games than solo ones. Results of the economic task were not included in the analysis because of poor reliability.
Aydin, 2020	Children	N=3034. Mean age at T1=11.21, sd=2.06, mean age at T3=13.12, sd=2.13.	Internet Gaming disorder Test (IGDT): self-report of 6 subscales of IGD symptoms.	Measure of Hostile Aggression Bias with six ambiguous scenes, children had to rate the level of aggressiveness intent in each of them.	No link between hostile bias and exposure to VVG was made.
MacGowan, 2021	Eight grade secondary school students	477 students	Internet Gaming disorder Test (IGDT): self-report of 6 subscales of IGD symptoms.	Reading the Mind on the Eyes (RMET), child version: 28 photography with only the region of the eyes displayed. Participants had to choose among four options the correct emotion displayed.	Poor negative emotion recognition seems to be linked to PG symptoms and may be vulnerability factors for PG.
	Children	73 typically developing children (39 female). Two assessments : T1 mean age=54.7	Mother reported time spent gaming in the past 7 days.	ToM was assessed using six tasks: Knowledge Access, Unexpected contents, Real-Apparent Emotion task, Smarties task, the Sally-Ann first order false belief task and a second order false belief task	At T1, gaming for boys negatively predicted ToM scores at T2. No link between ToM task and gaming time appeared for girls.

Hopp, 2018	Online survey	months, sd=2.8, T2 mean age=66.7 months, sd=2.8. N=312, 60.77% male, mean age=32.042, SD=9.927 795 students divided in three groups. Grade 5: n=232,	VG played were listed and then rated regarding their amount of violence and the frequency played.	Eight stories were used, for which participants had to rate the behavior and the intent as hostile, instrumental or benign.	No significant relationships were found between exposure to FPS military theme VG and hostile attribution bias.
Zhen, 2011	Adolescents in urban China, from schools	mean age=11.63, SD=0.57. Grade 8: n=247, mean age=14.82, SD=0.59. Grade 11: n=316, mean age= 16.80, SD=0.59.	VG played were listed and then rated regarding their amount of violence and the frequency played.	Presented with ambiguous stories, participants had to imagine and write down ten possibilities of what happened next. The number of aggressive possibilities was recorded.	Hostile expectations may be a mediator between exposures to VVG and physical aggression, but it appeared not significant for most of the subgroups (per grades or gender).
Moller, 2009	Secondary school students	3 waves of a longitudinal assessment: T1 (n=295, mean age=13.34, SD=.83) and T2 (30 months later, n=143).	VVG exposure was assessed with questionnaires regarding VG played and frequency.	Four scenarios were presented, in which participants had to decide if the harm made was on purpose.	Aggressive norms mediated the link between hostile attribution bias and exposure to VVG. Moreover, exposure to VVG at T1 seemed to impact aggression (measured by self-questionnaire) by increasing aggressive norms (measured with a self-questionnaire) and hostile attribution bias. No significant direct link between VVG and hostile attribution was found.
Eastin, 2009	Midwestern University	N=162, mean age=21.50, SD=.80, range= 18-41	VG experience was measured by assessing for how long participants have been playing and at which frequency and duration	Participants completed three ambiguous stories and had to decide what would happen next and what the character was feeling or thinking (20 answers). Answers were then split between aggressive and nonaggressive/hostile answers. Hostile expectations scores corresponded to the	The game experience was positively correlated with hostile attribution bias: the highest the experience was, the highest the hostility bias.

				number of hostile answers divided by the total number of answers (hostile or not).	
Gentile, 2009 (first of the three studies)	Singaporean secondary school children	7th grade: n=446. 8th grade: n=281. Mean age=13.0, SD=0.79.	Frequency of gaming, the content of games played and the number of hours per week played were rated.	Six ambiguous stories were used, and participants had to explain the event.	A negative correlation was found between exposure to prosocial VG and hostile attribution bias, while VVG exposure was positively correlated with hostile attribution bias.
Krahe, 2004	8th-grade students	N=231, mean age = 13.6, SD=0.63.	Exposition to VVG was measured by self-reports of liked and played games, frequency and duration of use. The rating of violence was led by two groups of experts.	Four scenarios were proposed in which participants had to rate the hostile intent.	No significant correlation between frequency of VVG use and hostile attribution bias was found.
Funk, 2003	Children	8- to 12-years-old group: n=35, mean age=10.14 years, SD=0.97. 5- to 7-years-old group: n=31, mean age=5.61, SD=0.62.	Self-reports revealed gaming frequency and content. This study also studied the short-term impact of gaming.	Ten drawings depicting stories in which empathy or aggression is induced were read to children. Children had to say what follows (ToM) and how they would react. A higher score for empathy vignettes indicated higher empathy responses, and a higher score for aggression indicated higher aggressive responses.	Regression statistics showed a link between exposure to VVG, that predicted scores in empathy vignettes in which a higher exposure to VVG was related to lower scores on empathy vignettes.

Social decision-making (comparison between groups)

Su, 2018	College students from Fuzhou University, players of 'League of Legends'	Problematic Internet Game Use (PIGU): n=23. Occasional Internet Game Use (OIGU) : n=23.	PIGU group was composed of participants with a score ≥ 50 on the IAT, at least 14 hours of Internet gaming per week, with gaming as the principal activity among Internet activities. OIGU group was composed of participants with a score ≤ 50 on the IAT, no	Both economic games were played with a friend, with a recently met experimenter who played with the participant just before, and a stranger. Prisoner's dilemma (PD): one-shot, participants can give from 0 to 10 talers. Talers given were doubled if the other participant cooperated, and lost if the other did not cooperate. Chicken game (CG): one-shot, the riskiest choice was to defect.	No significant difference was found on the PD task, but there was a lower tendency to cooperate in the PIGU group than the OIGU on the CG task. Both groups were more cooperative with their friends, but only the PIGU group displayed levels of cooperative behavior comparable between friend and the game mate just met in the CG task.
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Jin, 2017 (only study three is presented)

Undergraduate students from Sichuan University, China

N=132, 102 men, mean age=18.93, SD=2.01, range= 18-21. Experienced players: 67 participants. Inexperienced players: n=67.

more than 7 hours of gaming per week for at least one year. Groups were composed based on the total playing game score, 25% of the highest comprised the experienced group while 25% of the lowest score comprised the inexperienced group. Three experimental conditions were then made: 2 players from the same group (experienced or non-experienced) did the task together, or one player of each group (experienced and non-experienced) did the experience together.

Social dilemma task: 10 trials, 1 yen for each trial. Participants can give coins to the partner and then double it if the other also cooperates or lose if they did not.

Inexperienced gamers tended to be more cooperative than experienced gamers, even when controlling for experimental conditions.

Aggressive behavior

Comparison between groups

Pichon, 2021

Same as previously explained in this table.

Same as previously explained in this table.

Same as previously explained in this table.

Study 1: CRT with zero as a possible level of noise blast for the session 1.

Study 1: For the CRT, the AVGP group displayed higher level of aggression intensity than NVGP.

Engelhardt, 2011	Undergraduate students	Age range:18-22 years old.	Subgroup from 2000 undergraduates who filled a report on video habits (number of hours per week and violent content). One subgroup was randomly picked from the lowest 25th percentile (low exposure group), the other was picked randomly from the 75th highest score (high exposure group).	The CRT was used in which participants were told that they play a rapid game against another participant and that the loser would receive a noise of the duration and intensity decided by the winner. In reality, they played against a computer and had to choose intensity and duration as a measure of aggressive behavior. Participants either played a violent or a nonviolent VG and view violent or nonviolent photo under EEG before the CRT.	Participants who played an aggressive VG were more aggressive than the other group (mean=-0.59), and that effect was the same for participants with or without previous experience. The level of aggression was mediated by EEG measure of desensitization to violence for participants with low level of previous exposure to violent VG.
Arriaga, 2011	College students	N=58, mean age=22.6, SD=2.5, range=18-27	Participants were separated based on violent game habits (VGH, n=30, playing VVG for the past three months) and not having habits of playing violent games (non-VGH, that did not play a violent game for the past three months, n=28).	The CRT was used. Participants were then interviewed to know their motivations regarding their answers. Participants were also asked to play a violent or nonviolent VG before.	For non-VGH, comparing before and after playing, no difference was found regarding the level of aggressive behavior. For the VGH group, participants who played the violent VG displayed higher aggressive behavior than participants that did not play before.
<i>Correlation studies</i>					
MacGowan, 2021	Children	Same as previously explained in this table.	Same as previously explained in this table.	The prosocial behavior was only assessed at T2. It consisted on scenes with the experimenter (one in which the experimenter drops a tape, another in which the experimenter drops paperclips). Latency to help the experimenter was the measure of prosocial behavior..	Regarding prosocial behavior, no link was significant with time spent gaming, for both girls and boys.
Devilly, 2021	University students and non-students gamers	151 participants (141 university students, 10 non-student gamers recruited via announcements), 59 males (mean age=54.44, sd=8.95)	A questionnaire about media usage was used to assess weekly media usage, including type of media (TV, movies, VG).	Modified Taylor Competition Reaction Time Task (TCRTT) : include a "no sound" option to propose a non-violent answer.	Media exposure and specifically VVG exposure did not predict the level of aggression on the TCRTT.

		and 92 females (mean age=22.89, sd=7.72)			
Ferguson, 2010	Young adults from a Hispanic-serving public university	N=103, mean age=23.6, SD=2.82	VG habits were assessed with a self-report assessing frequency and violent content of games	The CRT was used. Before this task, participants had to play either a violent (high violent or morally acceptable violent games) or a nonviolent game or no game at all.	No link was found between previous exposure to VVG and aggression in the laboratory.
Ferguson, 2008 (first study)	Undergraduate students	N=101, mean age=20.9, SD=3.7, range=18-40	VG habits were assessed with a self-report assessing frequency and violent content of games	The CRT was used. Before participants were assigned to choose or not the VG they played (violent or not).	No significant effect of past VG exposure on aggressive behavior was found, and there was no interaction with VG play before the CRT.
Bartholow, 2006	Undergraduate students	N=39, mean age=19.5, only men (only 34 participants were included in the results)	VVG habits were assessed with a self-report assessing frequency and violent content of games	The CRT was used. Pictures (violent or not) were also presented while EEG was recorded.	VVG exposure was found to be highly correlated with the aggression scores. In the VVG players group, levels of aggression were found to be negatively correlated with the amplitude of P300 (reflecting information processing, in this study in reaction to violent pictures) components of EEG. A separate regression analysis showed that the more hours' participants spent on VVG, the greater they aggressed toward the other in the CRT . Additionally, the greater the difference in P300 between violent and nonviolent pictures (with higher reactions to violent pictures), the higher the aggression. Finally, when separating the frequency and content of the game, only the exposure to VVG and not the frequency was correlated to higher aggression scores.

Bartholow, 2005. Two studies. Only one assesses social cognition with cognitive measures.	Undergraduate students	Subset of participants of the other study described in the article (n=92, from 18 to 22 years old)	This study assessed the short-term effect of exposure to a VG and measured exposition to VVG.	The CRT was used, and violent VG or no violent VG was played before the CRT.	Participants with higher scores of exposure to VVG displayed more aggressive behavior than participants with a low level of VVG exposure, especially for those who played a VVG just before the CRT.
Tamborini, 2004	College students	N=182, 99 males, mean age=20.57, SD=1.52, range=18-30	Exposure to VVG and VG in general were assessed with a self-report of the amount of time spent playing VG.	Aggressive behavior was assessed with the evaluation of a research assistant. Participants were told that a volunteer applied for position at the laboratory and that they had to rate the courteousness, competency and worthiness of deserving financial support. Low scores on the researcher evaluation indicated a high level of aggressive behavior.	No variable was a predictor of aggressive behavior.

Moral Competence

Groups comparison

Sofia, 2019	Undergraduate students	N = 236, 20% of males.	Two subsamples were created from the global sample never/rarely play and play twice or more. The experimental group saw an excerpt of a VG moral dilemma at the end of the semester.	The Moral Competency Test (MCT) asked participants to rate the resolution of two moral dilemmas on a scale regarding their agreement with the resolution. A higher score showed high consistency in moral reasoning.	A positive correlation between frequency of play and MCT scores were shown where playing more was reflected in a higher score on the MCT, but only for those who were in the experimental condition and had to think about a specific moral dilemma.
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Correlation study

Krcmar, 2016	University students	N=65, median age=20	Frequency of VG play in last week and last month was rated.	Participants were told to play a VG and had to explained the reasons for each of their choices. Each choice was coded in strategic choice/reasoning (that would improve the character/progress in the game) and/or moral reasoning (irrelevant to the progress but reflected morality). For each moral choice, a rating on the foundation behind it was made (harm/care, fairness/reciprocity, in-group/loyalty, authority/respect, purity/respect).	Participants who played more reported playing more frequently weekly are more likely to use moral reasoning during VG. Moreover, VG use was significantly linked with the foundation of fairness/reciprocity.
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2.2.6. Discussion

This article aimed to review all studies assessing SC with neuropsychological tasks in relation to VG use or PG. Thirty-nine articles were found that examined several aspects of SC. Regarding *facial emotion processing* abilities, the study of conscious facial emotion processing showed mixed results, but the study of unconscious and cerebral processing suggested that a change in processing emotions can occur when participants display PG. Nevertheless, the multiplicity of methods and populations assessed did not allow us to conclude either better or worse abilities linked to VG use or PG. The results involving *empathy* abilities mostly showed no differences linked to the use of VG. *Attribution bias* studies showed mixed results with multiple populations assessed (children, adolescents, and adults). *Social decision-making* studies showed a change in the processing of social distance (assessed when playing with friends or strangers just met in the game) in the PG population. Studies also showed less cooperative behavior in the adult population linked to the use of VG with and without PG. Regarding *aggressive behavior*, the results were mixed and need further research. Nevertheless, half of the studies did not find a link between exposure to VG and CRT scores, and studies with PG are lacking. Finally, two studies showed that higher *moral competence* was linked to higher VG exposure when presented with a moral dilemma.

Gaming, face processing and empathy

The studies reviewed in this article are numerous, which shows the interest in and the importance of understanding the link between facial emotion processing and gaming. Nevertheless, the neuropsychological data did not clearly indicate either alterations or improvements in identifying emotions in faces but rather suggested cerebral changes in facial emotion processing. It is indeed known that PG patients

exhibit deficits in EEG studies and more precisely in the P300 component, which reflects attention allocation (Kuss, 2018). Moreover, it has been shown that excessive internet users also displayed altered early processing of faces on ERPs (He et al., 2011). Thus, studies have suggested changes in the cognitive processing of faces that need to be confirmed. The preservation of identification abilities also needs to be confirmed with other studies in regular VG players and PG patients.

Regarding empathy, no effects of VGs were found in studies using fMRI and diverse cognitive tasks. When using self-reports, such as the interpersonal reactivity index (IRI (M. H. Davis, 1983)), which comprises fantasy and perspective-taking subscales (two measures of cognitive empathy) and empathic concern and personal distress subscales (two measures of affective empathy), no stable associations were found with problematic internet use (Melchers et al., 2015). However, when another questionnaire, the Empathy Quotient (Baron-Cohen and Wheelwright 2004), was used, a link was found between lower levels of empathy and higher problematic internet use (Melchers et al., 2015). Furthermore, no differences were found when comparing problematic and nonproblematic VG players (Collins & Freeman, 2013). These data may suggest that PG is not associated with a diminution of empathy abilities. Nevertheless, many more studies are needed to make conclusions regarding the profile of empathy among gamers and specifically those with PG. For example, no study has explored empathy abilities through affective and cognitive components, such as those proposed in the substance use disorders population with the Condensed and Revised Multifaceted Empathy Test (MET-CORE) (Grynberg et al., 2017). This study showed an alteration in the cognitive ability to decode complex emotions but preserved sharing abilities (affective component, as

assessed by self-reports cited hereinabove). Thus, further studies are needed to explore whether PG is associated with the same patterns of alterations as observed with substance use disorders, which could suggest alterations in cognitive empathy abilities linked to addiction *per se* and not to the ingestion of neurotoxic substances.

Finally, in the general population, it has been shown that asking participants to feel empathy while in the fMRI scanner during an empathy-for-pain task created a bias for painful faces, with an overestimation of their intensity (Naor et al., 2020). This study showed that SC components such as empathy and facial emotion processing are not discrete functions and that they have to be measured together to evaluate the reciprocal impacts on each other.

Gaming, theory of mind and aggressive behavior and the general aggression model (GAM)

Studies assessing *ToM* and VG were mainly about attribution bias and showed mixed results, while *aggressive behavior* was mainly assessed with the CRT and obtained mixed results. For those two SC components, mainly correlational methods have been used, making interpretation more complex and less powerful. Two studies suggested that immediately after having played violent VGs, there was an increase in aggressive behavior, but only for gamers who frequently played (Bartholow et al., 2005, 2006). This aspect has not been explored in the PG population. This field of research was developed in relation to the general aggression model (GAM) (DeWall et al., 2011). This model postulated that repeated exposure to violent VG would impact cognition by increasing an individual's aggressiveness and then increasing aggressive behavior itself (Greitemeyer & Mügge, 2014). Thus, several meta-analyses have tried to highlight the impact of violent VGs on aggression and have shown that violent VGs seem to be linked to aggression (Anderson et al.,

2010; Bushman & Huesmann, 2006; Prescott et al., 2018); other meta-analyses have shown no effect of VGs on aggressive behavior (Elson & Ferguson, 2014; Ferguson & Kilburn, 2010; Sherry, 2001). Another meta-analysis nuanced these results and showed that VGs did impact social outcomes (behavioral, cognition, affect and arousal measures, all mixed in the analysis) by increasing aggressive cognitions and decreasing prosocial outcomes in the case of violent VGs and increasing prosocial outcomes and decreasing aggressive cognitions in the case of prosocial VGs (Greitemeyer & Mügge, 2014).

Studies regarding aggressive behavior are absent from the PG literature, and this topic needs further research. However, one study showed a link between symptoms of PG and scores on the RMET, suggesting the presence of *ToM* alterations that are associated with PG. On the other hand, the ability to infer mental states was positively linked with VG ranking, suggesting an advantage provided by this SC skill for VG performance.

Gaming, social decision-making and moral competency

Both studies assessing VG experience with and without addiction showed a tendency for less cooperation in experienced players. In the case of PG, the study by Su et al. (2018) showed less overall cooperation during the chicken game, suggesting a preference for risky situations or less cooperative behavior. Specificities in the pattern of responses were also found in nonsocial decision-making tasks in this population, with the same level of preference for risky decision-making (Dong & Potenza, 2016). Moreover, PG subjects tended to prefer short-term rewards (Dong & Potenza, 2014). Therefore, it is not clear whether these subjects choose riskier situations or display less cooperation *per se*.

Finally, during the chicken game experiment (Su et al., 2018), PG players tended to cooperate with game mates

as much as they did with friends and cooperated less often with occasional players, suggesting that game mates were processed as friends. PG participants, therefore, seem to present a specific pattern of relationships that may be altered in real life but not online. Regarding moral competence, both studies described in this review suggested an improvement in moral competence associated with VG frequency, highlighting a positive impact of VGs (Krcmar & Cingel, 2016; Sofia & Klimenko, 2019). The authors linked these results to the fact that players used to violent VGs tended to more easily emotionally connect with the character presented in the moral dilemma (Sofia & Klimenko, 2019).

Social decision-making has been explored in relation to PG and VG use, and research has shown that players' decision-making seems to be marked by decreased cooperation. Nevertheless, the response pattern of decision-making in those with PG showed a tendency to choose the riskiest options (Schiebener & Brand, 2017), explaining this lack of cooperation. More research is needed to untangle whether the tendency to cooperate is altered or is impacted by the tendency to make riskier decisions. Additionally, more research is needed to determine whether VG players show higher moral competence than nongamers and to explore this aspect in the PG population.

Problematic gaming and SC

Interestingly, all studies including PG participants found significant results when assessing SC abilities. Indeed, when presented with facial emotions, PG subjects displayed particular cerebral functioning in two studies (He et al., 2019; Peng et al., 2017). Compared to controls, a group of PG patients displayed a deficit in social perception of the same level as a group of patients with methamphetamine use disorder (Jiang et al., 2020). Additionally, lower scores on a ToM task seemed to be linked to internet GD symptoms (Aydm et al., 2020).

Finally, a group of PG patients displayed lower cooperation than control friends who played a VG (Su et al., 2018). These deficits can be linked with particularities highlighted on a cerebral level in adolescents (Schettler et al., 2022) and adults (Yan et al., 2021) with PG, particularly the hyperconnectivity of networks handling affective processes (limbic structures and cortex networks) and hypoconnectivity in structures handling cognitive control (such as frontoparietal areas) (Yan et al., 2021). Finally, studies assessing children and adolescents must be taken into account carefully because the brain and other cognitive functions are still under development and have to be considered in transition (Kilford et al., 2016).

On the other hand, no massive effect of exposure to VGs appeared in the experimental literature. It would have been interesting to assess addictive symptoms as a function of frequency or exposure to VGs to observe if, in the end, the differences observed in this literature search, specifically those that show alterations in SC, could be linked with an addictive profile. Indeed, as explained in Bandura's model, psychosocial functioning can be explained as individual factors, such as cognitive functioning, reciprocally interacting with environment and behavior (Bandura, 1986). In the context of VG use (behavior), the presence of alterations of SC (individual factor) may be a vulnerability factor that leads to addictive disorders. Reciprocally, the repetition of behavior and the time spent playing VGs may lead to alterations in SC. In the same way, social capital or relationships (the environment) reciprocally interact with VG use and alterations in SC. More longitudinal studies are needed to answer these questions.

Limitations

Limitations of the included studies

Most studies involved a small sample size, and most of them assessed students from universities, which is a bias

of recruitment. Moreover, most research assessing the effects of long-term exposure to VGs does not assess addictive symptoms, yet the presence of addictive symptoms can bias the results. Additionally, all included articles assessed only one component of SC and therefore did not permit the creation of SC profiles of participants, which could permit us to gather information regarding the links among SC components. Finally, most studies used correlation methods or comparisons of groups, but no longitudinal study was included, which does not permit us to make conclusions about the directionality of identified links.

Limitations of the review

Several limitations arose from the articles reviewed in this article. In particular, heterogeneity was the main characteristic of the research selected. Indeed, concerning the participants included (different age groups, definitions of PG and gaming intensity), methods used and components assessed, the multitude of differences did not permit a comparison between studies or the generalization of their results. In association with this heterogeneity, this review did not include a meta-analysis and, therefore, did not permit us to draw conclusions on specific alterations or preservation of cognitive functioning. Moreover, SC is a large concept that could benefit from a consensus about which components should be included and how to assess them. Regarding the information collected about PG, the main limitation was the lack of homogeneity in the methods used, which highlights the necessity to conduct new research linking PG and SC.

Future directions

This review showed that VGs have been investigated through the prism of SC but with many different methods and populations, leading to mixed results. Nevertheless, studies examining PG and SC remain scarce. Understanding SC abilities in VG players with or without addiction is essential to (i) better understand

mechanisms of addiction and (ii) better adapt the treatment of patients with PG with the creation of specific cognitive remediation programs that may focus on specific alterations in SC. Questions that remain unexplored are as follows: (i) whether offline relationships are impaired and whether deficits in SC or withdrawal from offline relationships because of an overinvestment in online relationships can explain it; (ii) are the difficulties related to offline relationships present before the development of PG, leading these individuals to play and socialize online (which would be the mark of an adaptive strategy), or conversely, are these difficulties triggered by the high amount of VG use, which cuts these individuals off from real-life relationships and provokes online investment as compensation; and (iii) do levels of SC deficits relate to levels of alterations observed in the PG population (specifically in social spheres such as school/work, family or friends)? The new recognition of GD will help the development of research and therapies that are still lacking.

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Constraints on publishing

All authors declare that there were no constraints on publishing.

Competing interests

EH, MBP and OB declare that they have no conflicts of interest.

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Les références sont incluses dans l'annexe Références du document complet.

Conclusion de la deuxième partie

Ces deux revues systématiques de la littérature ont ainsi mis en évidence le manque de recherches liant les capacités de CS avec le JAP et le JVP. Le premier article au sujet du JAP a répertorié un article suggérant des difficultés sur le plan du traitement des émotions non-verbales, tout en mettant l'accent sur la nécessité de croiser les données obtenues avec des données rapportées par les patients. Une mise à jour de cette revue a été effectuée en mars 2022 mais aucun nouvel article évaluant les compétences en CS *via* une tâche neuropsychologique dans le JAP n'a pu être identifié depuis septembre 2018. Le second état de l'art traduisait l'importance du questionnement sociétal concernant l'impact du JV sur la cognition et le comportement agressif. Concernant les études menées plus particulièrement sur le JVP, certaines particularités ont été mises en évidence sur le plan du traitement des émotions ou de la TdE, ou encore du comportement de coopération. Ces articles permettaient d'une part de faire le lien avec le profil observé dans les TUS, mais représentaient aussi des pistes thérapeutiques pour que la RC soit envisagée en tant que traitement complémentaire possible.

Ainsi, tous les articles trouvés dans les populations présentant un diagnostic de JAP ou de JVP suggèrent une altération des capacités évaluées. Par ailleurs, de nombreuses études utilisant des données rapportées par les patients démontrent des difficultés dans la vie quotidienne sur le plan du fonctionnement social. L'étude de la littérature a ainsi confirmé la nécessité d'étudier ce pan de la cognition qui pourrait expliquer certaines difficultés rencontrées par les patients et être travaillé grâce à des programmes de RC.

En outre, tous les articles recensés dans ces deux revues de littérature présentent des méthodologies diverses, et évaluent des composantes différentes de la CS. Ces études ne sont ainsi pas suffisamment nombreuses, la méthodologie suffisamment robuste, et le nombre de sujets évalués suffisamment important, pour pouvoir conclure à une altération globale ni un profil de compétences en CS dans les ACs. Il est ainsi nécessaire de poursuivre l'étude des habilités en CS des patients présentant une AC, en utilisant différentes tâches et données cliniques pour permettre de mieux comprendre le profil cognitif de ces patients.

Enfin, aucune étude identifiée dans ces revues n'avait mesuré la fréquence de jeu et le niveau de l'addiction en parallèle des compétences en CS. Or, ce type de recherche pourrait permettre d'affiner la compréhension du rôle de la CS dans l'émergence des processus addictifs.

Les recherches menées ainsi que les publications associées sont présentées dans la partie qui suit.

PARTIE 3. EXPERIMENTATIONS

Cette troisième partie présente les expérimentations menées pour mieux comprendre le profil de CS dans les ACs. La première recherche s'intéressait aux capacités d'allocation d'attention visuelle spatiale avec des indices sociaux chez des joueurs de poker en comparaison de contrôles. La seconde étude a évalué les compétences sur plusieurs composantes de la CS en population générale, en fonction de la fréquence de jeu (JV ou JHA). Enfin, la troisième étude se concentrait sur des patients du service d'addictologie de Nantes présentant un diagnostic de JAP et évalués sur un large panel de tâches neuropsychologiques.

Articles présentés dans cette partie :

- Manuscrit 3 : soumis dans *Journal of Behavioral Addictions* : Etude PERHAPS :

Hurel, E., Grall-Bronnec, M., Thiabaud, E., Leboucher, J., Leroy, M. & Challet-Bouju, G. Spatial attention to social information in poker: A neuropsychological study using the Posner cueing paradigm. Soumission intégrant les commentaires des reviewers effectuée.

- ❖ Recherche présentée lors de la 7ème édition de l'ICBA (International Conference on Behavioral Addictions), du 20 au 22 juin 2022, à Nottingham, sous le titre : « Attentional social information processing in a population of recreational poker players ».

- Manuscrit 4 : soumis dans *Journal of Behavioral Addictions* : Etude eSMILE

Hurel, E., Grall-Bronnec, & Challet-Bouju, G. Online assessment of social cognition in a population of gamers and gamblers: Results of the eSMILE study. Soumis.

- Manuscrit 5 : publié dans *Neuropsychiatric Disease and Treatment* : Etudes BANCO et BANCO2

Hurel, E., Grall-Bronnec, M., Thiabaud, E., Saillard, A., Hardouin, J.-B., & Challet-Bouju, G. (2021). A Case-Control Study on Behavioral Addictions and Neurocognition: Description of the BANCO and BANCO2 Protocols. *Neuropsychiatric Disease and Treatment*, 17, 2369–2386.

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3.1.MANUSCRIT 3 : Evaluation de l'attention aux indices sociaux dans le poker grâce au paradigme d'indication spatiale de Posner

3.1.1. Résumé en français du manuscrit 3

Cette recherche avait pour but de caractériser le traitement attentionnel des informations sociales dans un groupe de joueurs de poker réguliers sans addiction en comparaison à des sujets contrôles. En effet, notre objectif était d'observer si, en l'absence d'addiction, la pratique du poker pouvait être liée à des compétences de CS particulières.

Cette étude incluait deux groupes de participants : 30 joueurs de poker réguliers sans addiction (qui jouaient au moins 1 fois dans la semaine au Texas Hold'em Poker et depuis au moins 3 mois) et 30 volontaires contrôles (qui ne jouaient pas ou peu, c'est-à-dire moins d'une fois par mois).

Les participants ont effectué le paradigme d'indication spatiale de Posner incluant des indices sociaux (visages) pour évaluer l'allocation de l'attention envers des stimuli sociaux. Dans ce type de paradigme, les indices permettent de diriger l'attention vers une localisation qui peut ou non contenir une cible après. Les essais sont considérés comme valides lorsque l'indice est du même côté que la cible, et non-valides lorsque l'indice est à l'opposé de la cible. Manipuler la validité de l'essai permet d'évaluer l'engagement et le désengagement de l'attention envers les stimuli. Dans notre étude, les visages pouvaient exprimer une émotion (la surprise, le dégoût, la joie, la colère, la peur, la tristesse) ou aucune (neutre). Enfin, certains essais étaient subliminaux (délai entre le début de l'indice et le début de la cible inférieur à 200 ms) ou supraliminaux (délai supérieur à 200 ms). La condition supraliminale permettait d'observer la mise en place de l'inhibition de retour (IDR) qui fait augmenter les temps de réaction des essais valides.

Le groupe de joueurs réguliers a montré une augmentation de l'IDR durant la tâche de Posner. Cela signifie que dans les essais valides, les sujets de ce groupe ont pris plus de temps pour indiquer le côté de la cible dans la condition supraliminale en comparaison des contrôles.

Ces résultats suggéraient que les joueurs de poker réguliers avaient un traitement particulier des informations sociales. Les caractéristiques du jeu de poker peuvent expliquer ces particularités. En effet, l'augmentation de l'inhibition de retour peut permettre aux joueurs de ne pas traiter de nouveau une localisation qu'ils ont déjà traitée et gagner ainsi en ressources attentionnelles.

Spatial attention to social information in poker: A neuropsychological study using the Posner cueing paradigm

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3.1.2. Abstract

Background and aims: This research aimed to characterize social information processing abilities in a population of regular nondisordered poker players compared to controls.

Methods: Participants completed the Posner cueing paradigm task including social cues (faces) to assess attention allocation towards social stimuli, including the effect of the presentation time (subliminal *vs* supraliminal) and of the emotion displayed. The study included two groups of participants: 30 regular nondisordered poker players (those who played at least one time a week in Texas Hold'em poker games for at least three months) and 30 control participants (those who did not gamble or gambled less than once a month, whatever the game).

Results: The group of regular nondisordered poker players displayed an enhancement of the inhibition of return during the Posner cueing task. This means that in valid trials, they took longer to respond to the already processed localization in supraliminal conditions compared to controls. However, our results did not evidence any particular engagement or disengagement attention abilities toward specific types of emotion.

Discussion and Conclusions: These results suggest that regular nondisordered poker players displayed specific social information processing, which may be due to the importance to efficiently process social information that can serve as tells in live poker. The observed enhancement of the inhibition of return may permit poker players to not process a localization that has already been processed to save attentional resources. Further research regarding the establishment of the IOR in other forms of gambling and with non-social cues needs to be performed.

Keywords Poker– neuropsychology – social information processing – Posner cueing paradigm – gambling– inhibition of return

3.1.3. Introduction

Poker as a social game of skills

Poker is a social game involving a competition between players. Contrary to bank games, in which participants play against the bank and can expect to win in the short term but not to be beneficiaries in the long term, social games can allow long-term gains, provided that the players use the skill gap between them and their opponents to their advantage (Bjerg, 2010). Studies about the impact of skill on poker performances have emerged, but there is still a debate regarding the relative importance of chance versus skill. Hence, poker skills may be useful in the long term and are not always observable with only a few hands (Palomäki et al., 2020), suggesting a continuum between chance and skill (Fiedler & Rock, 2009). For example, the use of strategies was demonstrated to increase the probability of winning (DeDonno & Detterman, 2008), and rankings in a tournament can predict rankings in the following competitions (Croson et al., 2008). Another study demonstrated that ranks can be predicted by previous rankings, type of strategies used and experience in playing poker, and that skills would dominate chance after 1500 hands played (Potter van Loon et al., 2015). Nevertheless, other studies were more mitigated. Indeed, when giving the same cards to expert and nonexpert players in 60 hands of “Texas Hold'em” poker, the only significant difference was that the experts handled bad cards better than the controls (G. Meyer et al., 2013), showing the importance of chance.

Poker players' processing of social information

Among all the skills that may be involved in poker, players engaged in live poker have to efficiently process the social information displayed by their opponents (Billings et al., 2002), as it can serve as tells. Indeed, social information permits speculation on opponents' strategies and the prediction of their actions (opponent

modelling (Billings et al., 2002)). Some research has highlighted the importance of social information processing in poker (Palomäki et al., 2020). For example, in a simplified poker game, a study showed that the level of trustworthiness displayed by an opponent could modulate the wager (Schlicht et al., 2010). Gender displayed by opponents (Palomäki et al., 2016) and playing with a human or a computer (R. M. Carter et al., 2012) may also impact poker players' decisions. Additionally, research has shown a positive association between the self-reported quality of social competencies and performance in poker (Leonard & Williams, 2015). The cognitive assessment of social information processing can include the conscious identification of social stimuli (such as identifying an emotion displayed by supraliminal vocal or facial stimuli) or the unconscious processing of social stimuli (such as discriminating an emotion displayed by a face and presented subliminally, which is invisible). In such assessments, social stimuli, such as faces, can be used as cues to capture the attention towards one of two locations on a screen before the presentation of a target, which may be presented either at the cued or noncued location. The measurement of reaction times then allows us to evaluate the facilitating or costing effects of cues (Posner, 1980). The engagement of attention towards a cue is indeed supposed to facilitate the detection of the cued target, leading to faster reaction times. Furthermore, the disengagement of attention from a cue is supposed to slow uncued target detection. Nevertheless, stimulus-onset asynchrony (SOA, i.e., the delay between cue onset and target onset) also impacts attention allocation. Indeed, when SOA is greater than approximately 200-300 ms and up to 3000 ms (Samuel & Kat, 2003), the phenomenon of the inhibition of return (IOR) occurs, which is an adaptive mechanism that prevents an already processed localization from being processed again and allows more attentional resources to be allocated to information located

elsewhere (Klein, 2000; Tang et al., 2015). This results in slowing the detection of the cued target while accelerating the detection of the noncued target.

Objectives and hypotheses

In the present study, we were interested in determining whether a regular poker practice, defined as a repeated regular exposition to poker playing, is associated with specific social information attention abilities; To this end, we compared these abilities, which were assessed using a spatial cueing paradigm, between regular nondisordered poker players and controls with no or limited poker experience. Moreover, we were also interested in determining the types of emotions that are better processed by regular nondisordered poker players compared to controls.

For trials with an SOA lower than 200 ms, it is possible to assess the engagement and disengagement of attention towards emotional cues (faces) without the establishment of the IOR. We hypothesized that regular nondisordered poker players would display overall higher social information attention abilities than controls. In this case, lower reaction times (benefit) may be observed for cued trials (i.e., facilitation of the detection of the target due to the previous engagement of attention by the cue displayed at the same location) and higher reaction times (cost) may be observed for noncued trials (i.e., the cost related to disengaging attention from the location of the cue before detecting the target at the opposite location), regardless of the facial emotion type. Moreover, we hypothesized that regular nondisordered poker players would display higher information attention abilities compared to controls for the types of emotion that may be useful in the context of poker, i.e., joy, sadness, and surprise. This would result in higher benefit effects and lower cost effects in poker players compared with controls for trials with these emotions as cues.

In the case of trials with an SOA greater than 200 ms,

the IOR is supposed to appear, which can lead to reversed effects on Posner's paradigm, i.e., costs instead of benefits for cued trials and benefits instead of costs for noncued trials. Regardless of the emotion explored, we hypothesized that regular nondisordered poker players would display a higher IOR effect than controls, which would result in a lower benefit effect for cued trials and a higher cost effect for noncued trials. Similarly, we expected a higher IOR effect for regular nondisordered poker players for the types of emotion that may be useful in the context of poker, i.e., joy, sadness, and surprise. This would result in lower benefit effects and higher cost effects for these emotions in nondisordered poker players than in controls.

3.1.4. Methods

This study is part of the PERHAPS research program (NCT02590211), which aims to assess the cognitive functioning of poker players with or without a gambling disorder.

Participants

This study included two groups of participants. The first group comprised regular nondisordered poker players (RPPG, $n=30$). A regular playing was defined as a repeated exposition to playing Texas Hold'em poker games, i.e. at least once a week for at least three months. All regular players had to play poker in the live version, so that they had the chance to accrue knowledge pertaining to social cognitive processing. They could also play online but not exclusively.

The control group (CG, $n=30$) included nonpoker players and participants who gambled less than once a month (poker or other gambling activities).

All participants were recruited from February 2017 to May 2018 through media announcements and from the registry of volunteers for research established by the research team.

Inclusion and noninclusion criteria

We included only men aged between 18 and 60 years

old who presented correct vision and hearing (even after correction). We did not include women because more men tend to play poker (McCormack et al., 2014) and we anticipated that the gender ratio may have been very unbalanced between the two groups and would have introduced a bias. The other noninclusion criteria were as follows: (i) participants who had taken part in a pharmaceutical trial during the previous month; (ii) those who presented colour blindness; (iii) those who presented severe depression (assessed with the BDI-13); (iv) those who presented a high level of anxiety (assessed with the STAI-YB); (v) those who presented heart problems and/or had electrical implants; (vi) those who were under a gambling ban procedure; (vii) those under a guardianship or curatorship; (viii) those with any history of neurological diseases, such as a history of seizures; (ix) those who had a physical condition that could disturb the assessment; (x) those who presented a nonstable current psychiatric disorder (assessed with the MINI); (xi) those who presented gambling disorder (assessed with the NODS); (xii) those who displayed a cognitive impairment (assessed with the MMSE); and (xiii) those who had used any psychoactive substance (self-declared) in the 8 hours preceding the assessment (except for nicotine).

Measures used for inclusion and confounding factors

The *Mini International Neuropsychiatric Interview* (MINI) (Lecrubier et al., 1997) is a structured interview investigating mood, anxiety and addictive (substance) disorders, and psychotic syndrome.

The *National Opinion Research Center DSM-IV Screen for Gambling Problems* (NODS) (Gerstein et al., 1999) is a structured interview investigating the DSM-IV diagnostic criteria for pathological gambling. We used a modified version to follow DSM-5 changes (American Psychiatry Association, 2013) (i.e., removing the item exploring illegal acts and using a

threshold of 4 instead of 5).

The *13-item Beck Depression Inventory* self-report questionnaire (BDI-13) (Beck et al., 1988) is a questionnaire assessing the level of depression. A score ≥ 16 indicates a severe level of depression.

The trait version of the *State-Trait Anxiety Inventory* self-report questionnaire (STAI Y-B) (Spielberger, 1999) assesses anxiety. A score ≥ 56 indicates a high level of anxiety.

The *Mini Mental State Examination* (MMSE) (Folstein et al., 1975) assesses the global cognitive level. A score ≤ 24 indicates cognitive impairment.

Measures used to investigate social attention allocation

We used the *Posner Cueing Paradigm* (or Spatial Cueing Paradigm) to assess attention engagement and disengagement towards social cues. This paradigm includes a cue to allocate the participant's attention to a location that may later contain a target and manipulates the spatial validity between the location of the target related to the location of the cue (Hayward & Ristic, 2013; Posner, 1980).

For each trial, two grey boxes (5.3 cm height x 3.0 cm width) appeared symmetrically on each side of a fixation cross for 1000 ms. Then, a cue appeared on the centre of one of the two boxes for 17 ms (subliminal condition, automatic processing) or 500 ms (supraliminal condition, strategic processing, supposed to trigger the IOR).

The cue was a picture of a face displaying an emotion (surprise, disgust, joy, anger, fear, sadness or neutral), which was the same size as the grey boxes and extracted from the Karolinska Directed Emotional Faces (KDEF) corpus (Lundqvist et al., 1998). In order to select which pictures to use, we performed a preliminary validation study on 15 volunteers using a procedure adapted from Bradley et al (1999). Each picture from the KDEF corpus was rated by ten volunteers. They had to rate

how much the picture elicited each of the following six emotions: surprise, disgust, joy, anger, fear, sadness, on a scale from 1 (not at all) to 6 (extremely). Emotional pictures were retained only if the mean rating of the corresponding emotion was higher than 3.5 and if the mean ratings of the other emotions were at least one point below the mean rating of the corresponding emotion. Neutral pictures were retained only if the mean ratings of all emotions were under 2. Pictures with too much luminosity were removed. Finally, we selected only the four best pictures for each emotion (surprise, disgust, joy, anger, fear, sadness or neutral), i.e. those which had the higher mean rating of the corresponding emotion for emotional pictures and those which had the lowest mean ratings of all emotions for neutral pictures. A mask without any stimulus (the two grey boxes) was then displayed for 17 ms in the subliminal condition and 50 ms in the supraliminal condition. Afterwards, a target (a black circle with a 0.3 cm diameter) appeared on the lower half of one of the grey boxes for 2000 ms or until the participant responded (see Figure 6). This shifted down presentation of the cue, and the target was chosen to avoid a masking forward effect (i.e., when the face cue masks the following target) (Fox et al., 2002). Participants were instructed to localize the target as quickly as possible by pressing the extreme left or right button on a 7-button response pad. When the target appeared at the cued location, the trial was considered valid; otherwise, the trial was considered invalid. For noncued trials, rectangles were also presented in both conditions (sub- and supraliminal) but without pictures, followed by the mask (also for 17 ms or 50 ms). This type of trial was a control measure of reaction times without cueing (without the previous allocation of attention). To prevent automatic responses, the intertrial intervals randomly (without replacement) varied for 500, 750, 1000 or 1500 ms.

Each participant underwent 224 trials. Half of the trials (112) were valid, one quarter (56) were nonvalid, and

one-quarter were noncued. Half of each type of trial (valid, nonvalid and noncued) was supraliminal, and half was subliminal. For each type of trial (valid, nonvalid and noncued) and each presentation (supraliminal and subliminal), each of the 7 emotions was displayed the same number of times on the left and on the right.

The presentation order of the type of trials, presentation times and type of emotions was randomized. At the beginning of the task, participants practised for eight trials (4 valid, 2 nonvalid and 2 noncued) with pictures that were not used for the rest of the task. A break was added at the end of the 112th trial to avoid fatigue. Anticipative answers (i.e., in which participants answered in less than 250 ms) were excluded before data processing.

The outcomes recorded were reaction times and errors (omissions, i.e., the participant did not answer, or commissions, i.e., the participant chose the wrong side). Regarding the outcomes calculated, the benefit index (reaction time of noncued trials – reaction time of valid trials) reflects the decrease in reaction times due to the previous engagement of attention induced by the cue in a valid subliminal trial compared to a noncued subliminal trial. In the supraliminal condition, the benefit index was expected to decrease because of the higher reaction times in valid trials due to the IOR onset. Moreover, the cost index (reaction time of nonvalid trials – reaction time of noncued trials) reflects the increase in reaction times due to the necessary disengagement of attention from the location of the cue in a nonvalid subliminal trial compared to a noncued subliminal trial. In the supraliminal condition, the cost index was expected to decrease because of the lower reaction times in nonvalid trials due to IOR onset.

Procedure

After screening for eligibility, an appointment was proposed in the research centre to proceed with the

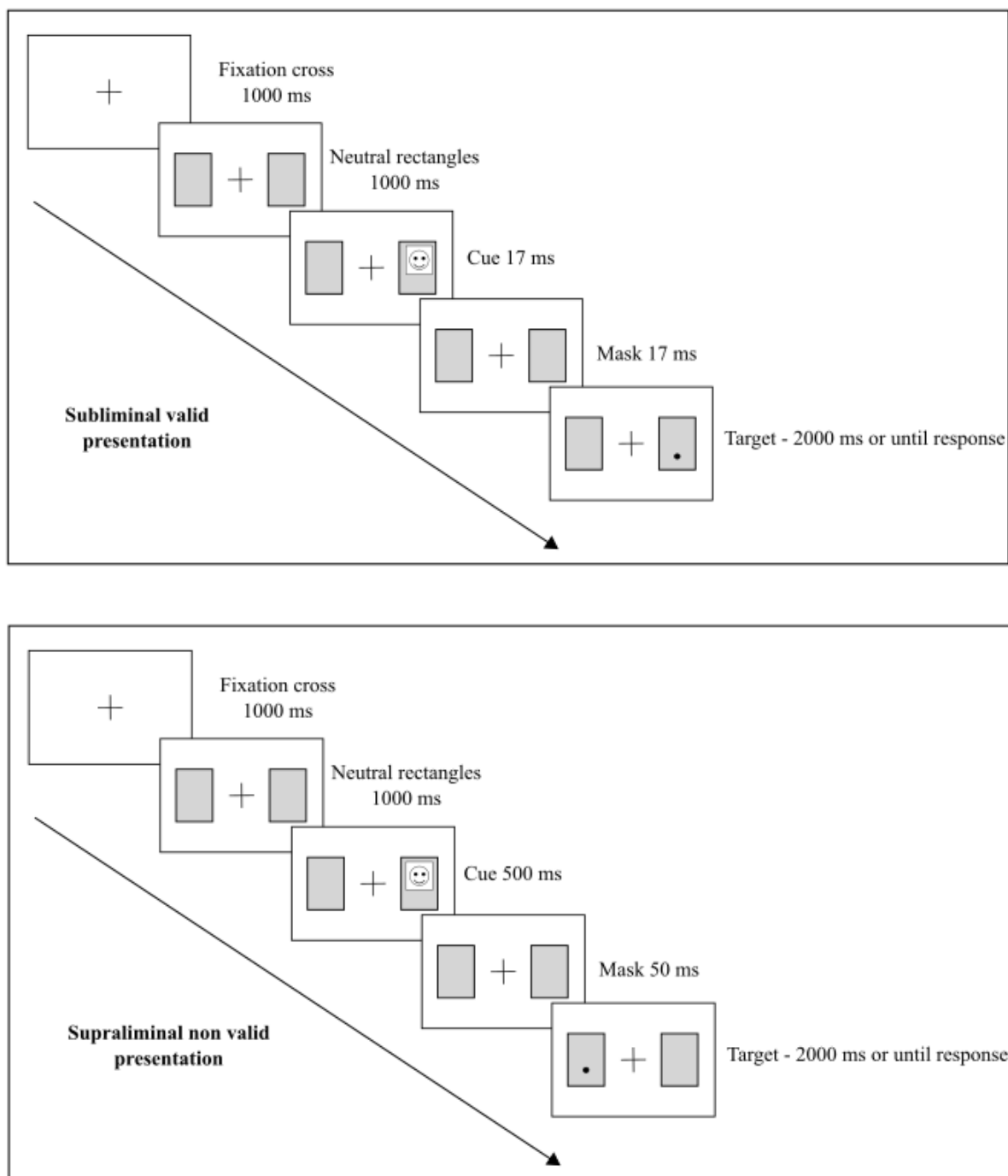


Figure 6 Flow diagram of the Posner cueing task

inclusion and carry out the research visit. Sociodemographic data (age and educational level), concomitant treatments and measures for inclusion were first collected. Then, the participants completed a subset of 5 cognitive tasks, including the Posner Cueing Task, with a total duration of 2 hours. The task order was randomized for each participant, but the Posner Cueing Task was always performed first (to avoid alterations in attention). The Posner Cueing Task was computer-administered.

All participants were seated in a quiet room and positioned 60 cm from the screen. Computerized tasks were programmed using Superlab 5 (Cedrus Corporation, San Pedro, CA, USA), and the 7-button response pad RB-730 (Cedrus Corporation) was used to record the participants' responses.

Participants received 30€ at the end of the appointment in compensation for their participation.

Statistical analysis

A descriptive analysis was performed to determine the mean and standard deviation of all variables.

To consider possible confounding factors that may have affected attentional performance, age, education level, MMSE score, BDI score, STAI score, concomitant treatment and current mood, and anxiety, psychotic and alcohol or substance use disorders were compared between the two groups using non-parametric tests (Mann-Whitney or Fisher's exact test). Given the sample size, we used the threshold of $p < 0.10$ to include the corresponding potential confounding factor as a covariate in the subsequent statistical analyses.

Then, two linear mixed models with a random effect on the intercept were used, with Group (RPPG/CG), Emotion (surprise/disgust/joy/anger/fear/sadness/neutral) and Presentation time (supraliminal/subliminal) as fixed effects, and the benefit and cost indices as the dependent measures. For the two models, we included the

interactions between Group and Emotion and between Group and Presentation time. We used a backward selection procedure starting with a model of the form:

$$Y_{ipe} = \beta_0 + u_i + \beta_1 \times group + \beta_2 \times presentation + \beta_3 \times emotion + \beta_4 \times group \times presentation + \beta_5 \times group \times emotion + \beta_6 \times covariates + e_{ipe}$$

where Y_{ipe} is the outcome of interest (benefit index or cost index) of the participant i for presentation p and emotion e , β_0 is the common intercept, $u_i \sim N(0, \sigma_1^2)$ is the random intercept, β_1 is the group effect (poker vs. controls), β_2 is the presentation effect (supraliminal vs. subliminal), β_3 is the vector of effects for emotions (ref = neutral), β_4 is the coefficient for the interaction term group*presentation, β_5 is the vector of coefficients for the interaction terms group*emotion, β_6 is the vector of coefficients for the covariates, and $e_{ipe} \sim N(0, \sigma_2^2)$ is the residual variance.

We first tested the interaction term β_4 with a Wald test and β_5 with a joint test, before testing the other main effects. At each step, the term with the largest p-value was removed from the model, and a new model was estimated. In the final model, we estimated the variance explained by the fixed effects and by both the fixed and random effects by calculating pseudo R^2 values (Snijders & Bosker, 1994).

Statistical analyses were performed using Stata 17.0 software. We used the **mixed** command to fit the linear mixed models with maximum likelihood estimation, and used the **margins** command to compute the adjusted predictions (estimated means) from the final model and to estimate the corresponding contrasts. All model assumptions (normality and homoscedasticity of the residuals and the BLUPs (Best Linear Unbiased Predictions) of the random effects) were tested and satisfied.

Ethics

The PERHAPS protocol received approval from the French Research Ethics Committee (CPP) on September 12, 2016. All participants were informed about the study and provided their written informed consent.

3.1.5. Results

Sociodemographic, clinical, and gambling characteristics

The two groups differed for four potential confounding factors at the threshold of $p < 0.10$, namely, age

($p=0.021$), level of education ($p=0.028$), score on the MMSE ($p=0.030$) and score on the BDI ($p=0.079$) (see Table 9). Consequently, these four variables were included in all comparative analyses as covariates. Regarding the gambling profile, only 5 participants from the CG declared that they had played poker during their lifetime, of which only 2 declared that they played less than once a month in the past year. Regarding the other gambling activities, only 2 participants from the RPPG bet on sports more than once a week. Otherwise, no gambling activity was practised at this frequency.

Tableau 9 Sociodemographic, clinical, and gambling characteristics - Manuscrit 3

Variables	Control Group (CG) n=30	Recreational Regular Poker Player Group (RNDPPG) n=30	p
Mean (sd) or n			
Sociodemographic characteristics			
Age	29.13 (10.2)	33.23 (7.8)	0.021
Level of education (years)	14.7 (1.95)	13.33 (2.59)	0.028
Clinical characteristics			
MMSE score	29.41 (0.9)	28.87 (1.1)	0.030
BDI score	1.23 (2.5)	1.83 (2.1)	0.079
STAI score	31.8 (8.6)	33.5 (7.2)	0.382
Presence of concomitant pharmacological treatments	2	5	0.143
MINI diagnosis (number of subjects with a positive diagnosis)			
Actual mood disorder	1	1	1.000
Actual anxious disorder	1	1	1.000
Actual addictive disorder	2	4	0.286
Actual psychotic disorder	1	0	1.000
Gambling characteristics			
Number of games currently played	Number of participants per number of games		
0	17	0	
1	9	3	
2	3	9	
3	1	9	
4	0	4	
5	0	5	
Frequency of games played			

Lottery (number of players who had already played in their lifetime)	22/23	29/30
<i>Current frequency (past 12 months)</i>		
<i>More than once a week</i>	0	1
<i>Once a week</i>	0	4
<i>Once or more a month</i>	0	2
<i>Less than once a month</i>	9	11
<i>Did not play in the actual period</i>	13	11
Slot machines (number of players who had already played in their lifetime)	12/23	22/30
<i>Current frequency (past 12 months)</i>		
<i>More than once a week</i>	0	0
<i>Once a week</i>	0	0
<i>Once or more a month</i>	0	1
<i>Less than once a month</i>	2	7
<i>Did not play in the actual period</i>	10	14
Blackjack (number of players who had already played in their lifetime)	2/23	14/30
<i>Current frequency (past 12 months)</i>		
<i>More than once a week</i>	0	0
<i>Once a week</i>	0	0
<i>Once or more a month</i>	0	2
<i>Less than once a month</i>	0	3
<i>Did not play in the actual period</i>	2	9
Horse race betting (number of players who had already played in their lifetime)	9/23	15/30
<i>Current frequency (past 12 months)</i>		
<i>More than once a week</i>	0	0
<i>Once a week</i>	0	0
<i>Once or more a month</i>	0	1
<i>Less than once a month</i>	1	6
<i>Did not play in the actual period</i>	8	8
Sport betting (number of players who had already played in their lifetime)	11/23	26/30
<i>Current frequency (past 12 months)</i>		
<i>More than once a week</i>	0	2
<i>Once a week</i>	0	1
<i>Once or more a month</i>	0	3
<i>Less than once a month</i>	4	15
<i>Did not play in the actual period</i>	6	5
<i>Not known</i>	1	

Poker (number of players who had already played in their lifetime)	5/23	30/30
<i>Current frequency (past 12 months)</i>		
<i>More than once a week</i>	0	26
<i>Once a week</i>	0	4
<i>Once or more a month</i>	0	0
<i>Less than once a month</i>	2	0
<i>Did not play in the actual period</i>	3	0

Bold p-values are those under the threshold of 0.10, and the corresponding variables were including as covariates in the subsequent analyses.

Regarding the RPPG, poker players all had poker as their preferred type of gambling among all the games they experimented, even if the large majority of them also played to other gambling activities. They all played both live and online poker, but more than half of them (53.3%) preferred gambling live poker. They started gambling on average at 15 years old ($m=14.9$, $sd=3.9$), and were mainly initiated through scratch cards (66.7%) or poker (13.3%). They had on average a regular practice of gambling for close to 10 years ($m=9.6$, $sd=6.1$).

Posner cueing task

Benefit index

The estimated coefficients of the linear mixed model for the benefit index are presented in Table 10, and effects are plotted in Figure 7. The variance explained by the fixed effects was 5.7% and the variance explained by both the fixed and random effects was 16.5%.

Tableau 10 Final model from the linear mixed model analysis on the benefit index -Manuscrit 3

Variables	Coefficient	Standard error	Confidence interval	p value
Group (ref. CG)	-5.69	4.90	[-15.29 ; 3.92]	0.246
Presentation (ref. subliminal)	-1.25	3.48	[-8.07 ; 5.58]	0.720
Group x Presentation	-10.54	4.88	[-20.11 ; -0.97]	0.031
<i>Covariates</i>				
<i>Age</i>	<i>-0.29</i>	<i>0.23</i>	<i>[-0.16 ; 0.74]</i>	<i>0.213</i>
<i>Level of education (years)</i>	<i>0.29</i>	<i>1.00</i>	<i>[-1.67 ; 2.25]</i>	<i>0.769</i>
<i>MMSE score</i>	<i>-2.79</i>	<i>2.25</i>	<i>[-7.20 ; 1.63]</i>	<i>0.216</i>
<i>BDI score</i>	<i>1.61</i>	<i>0.90</i>	<i>[-0.15 ; 3.37]</i>	<i>0.074</i>

Italic lines represent the covariates integrated in the model as potential confounding factors.

There was no significant effect of the type of emotion on the benefit index. With the supraliminal presentation, the benefit index in the RPPG group was 16.2 points [95% CI: -25.8; -6.6] lower than in the CG ($p<0.001$). With the subliminal presentation, this difference was not significant (-5.7 [-15.3; -3.9], $p=0.246$).

Moreover, there was no significant effect of the presentation time in the CG (-1.2 [-8.1; 5.6]. However, for the RPPG, the benefit index with the supraliminal presentation was 11.8 [-18.5; -5.1] points lower than with the subliminal presentation. This seems to reflect the establishment of an IOR in supraliminal trials, that was stronger for the RPPG compared to the CG.

Cost index

The estimated coefficients of the linear mixed model for the cost index are presented in Table 11, and effects are plotted in Figure 8. The variance explained by the fixed effects was 5.4% and the variance explained by both the fixed and random effects was 18.9%.

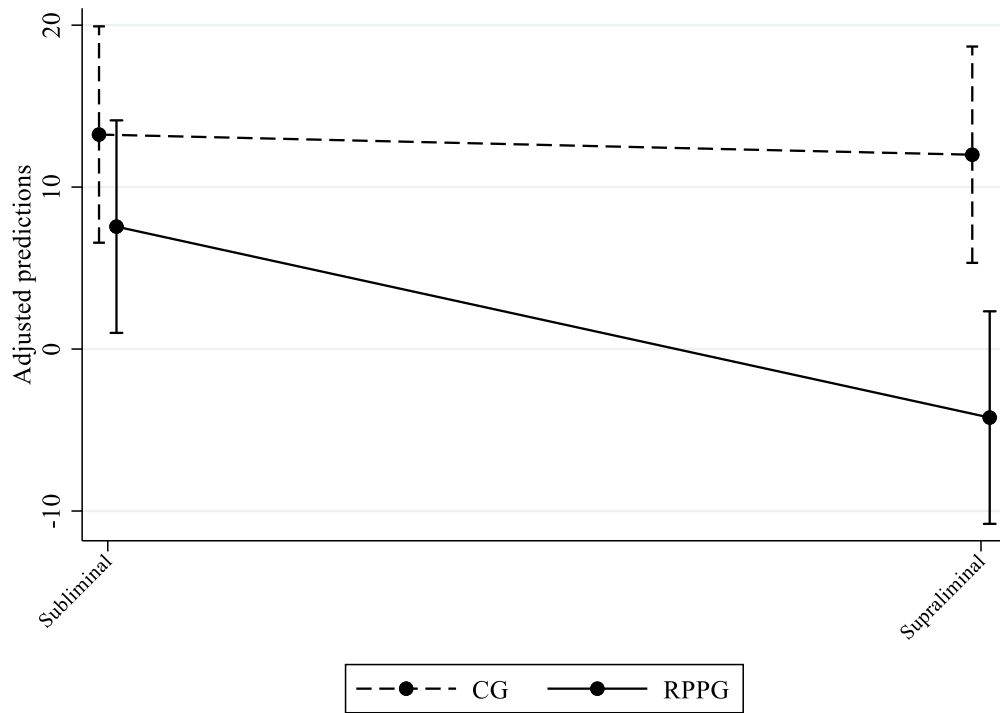


Figure 7 Adjusted predictions and 95% confidence intervals of the benefit index from the final model - Manuscrit 3

Vertical bars represent the 95% confidence intervals of the adjusted predictions. CG: Control Group; RPPG: Regular Poker Player Group

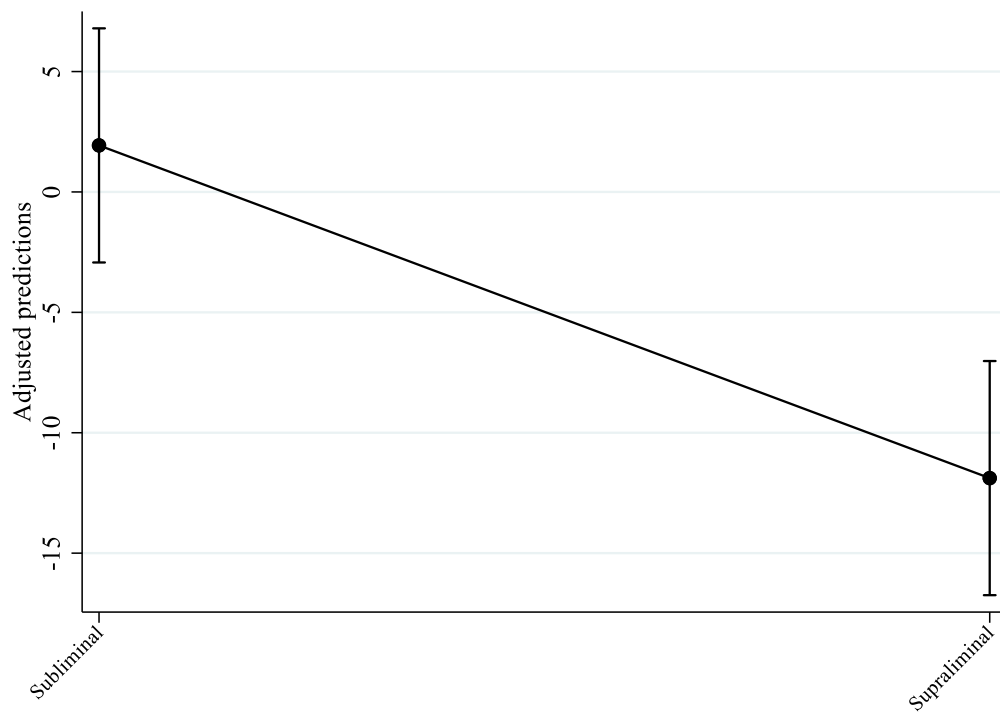


Figure 8 Adjusted predictions and 95% confidence intervals of the cost index from the final model - Manuscrit 3

Vertical bars represent the 95% confidence intervals of the adjusted predictions.

Tableau 11 Final model from the linear mixed model analysis on the cost index- Manuscrit 3

Variables	Coefficient	Standard error	Confidence interval	p value
Presentation (ref. subliminal)	-13.82	2.85	[-19.40 ; -8.23]	<0.001
<i>Covariates</i>				
<i>Age</i>	<i>0.51</i>	<i>0.23</i>	<i>[0.05 ; 0.96]</i>	<i>0.030</i>
<i>Level of education (years)</i>	<i>2.25</i>	<i>1.02</i>	<i>[0.26 ; 4.24]</i>	<i>0.027</i>
<i>MMSE score</i>	<i>1.52</i>	<i>2.28</i>	<i>[-2.95 ; 5.99]</i>	<i>0.505</i>
<i>BDI score</i>	<i>-1.42</i>	<i>0.92</i>	<i>[-3.22 ; 0.38]</i>	<i>0.122</i>

Italic lines represent the covariates integrated in the model as potential confounding factors.

There was no significant difference on the cost index between CG and RPPG. The cost index with the supraliminal presentation was 13.8 [-19.4; -8.2] points lower than with the subliminal presentation.

3.1.6. Discussion

This study assessed the social allocation of attention in poker players with repeated regular exposition to poker playing compared to controls with no or limited poker experience, using a Posner paradigm task. Regardless of the group, this study showed that the disengagement of attention was facilitated in nonvalid supraliminal trials compared to nonvalid subliminal trials. When comparing the two groups, this study showed that the IOR was higher for the poker player group than the CG. Indeed, the analysis of nonvalid trials showed that the cost index diminished significantly in supraliminal trials. These results suggest that the nonvalidity slowing is especially linked to lower SOA and that higher SOA already permits disengaging from nonvalid cues. This may also be linked with the establishment of the IOR. Indeed, the further the target is from the cue in the supraliminal condition, the faster the reaction time (Bennett & Pratt, 2001). The IOR may facilitate re-engagement towards another localization.

Our study also showed that poker players displayed a higher decrease of the benefit index in the supraliminal condition compared to controls. These results suggest that the IOR of poker players is enhanced compared to that of controls. This type of result has already been

observed in a population of cannabis users (Vivas et al., 2012) (see (Colzato & Hommel, 2009) for opposite results) and cocaine users after taking a dose of dextroamphetamine (Fillmore et al., 2005). The enhanced IOR found in these populations suggests that the IOR can be improved by the ingestion of drugs, such as cannabis. Nevertheless, the mechanisms are still not understood (Vivas et al., 2012). Other studies, gathered in a systematic review, have assessed the effect of alcohol, ecstasy, and hallucinogens. Nonetheless, only the absence of a difference or a lower IOR was evidenced (Olthuis & Klein, 2012). As for drugs use, repeated poker practice may also impact the IOR. Conversely, an optimal IOR may be helpful to win a poker game, and those with a good IOR may tend to continue playing poker because of this advantage.

Interestingly, a trend towards an enhanced IOR has also been found in a group of patients with Asperger syndrome (Rinehart et al., 2008) but not in patients with autism spectrum disorders (Antezana et al., 2016; Lin et al., 2020). In patients with Asperger syndrome, this result was linked to the fact that this population displays improved attentional visual search efficiency. Thus, it would be interesting to see if poker players also display a better visual search efficiency or if an enhanced IOR is only present when social cues are presented.

As the IOR seems to be helpful not to process a localization that has already been assessed (Klein, 2000; Satel et al., 2019), this enhancement may be a sign of a better attentional system in poker players. Indeed,

diminishing the refreshment rate of information permits increasing the amount of information that can be processed, which may be very helpful in the practice of poker. Thus, this enhanced IOR may reflect attention particularities linked with the practice of poker, in which social information needs to be processed efficiently.

Moreover, this research did not evidence any particular engagement or disengagement attention abilities toward specific emotions. This is contrary to our hypothesis that regular nondisordered poker players would display higher information attention abilities compared to controls for the types of emotion that may be useful in the context of poker, i.e., joy, sadness, and surprise. Indeed, the *processing efficiency hypothesis* (Calvo et al., 2006; Gordillo León et al., 2021) postulates that negative stimuli (especially fear) is processed more efficiently than neutral or positive stimuli to react more quickly. For example, in studies regarding spatial attention, fear is the main emotion that is known to automatically capture attention (Bannerman et al., 2009). This hypothesis would explain why lower attentional resources are needed to identify fear and therefore increase reaction speed (Calvo et al., 2006). Anger can be included in this theory as well (Pinkham et al., 2010). Nevertheless, our study did not show a significant advantage of any kind of facial cues compared to neutral facial cues.

Finally, beyond social information processing assessed by neuropsychological tasks, higher self-reported interpersonal relationships quality has been cited as a predictor of good poker abilities (Schiavella et al., 2018). Interestingly, lower level of interpersonal relationships quality was linked with higher level of addiction in poker players (Schiavella et al., 2018), and an alteration of conscious social information processing was also evidenced in a group of patients with gambling disorder compared to controls (Kornreich et al., 2016). Therefore, higher social cognition abilities may be a

marker of good skills in poker while lower social cognition abilities may be a feature of addictive disorders. It is thus important to confront results obtained with samples of poker players with and without a gambling disorder to identify what cognitive processes are linked to a repeated but non pathological poker practice to those related to the addictive process. This may provide useful knowledge to clinicians and researchers specialised in gambling and gambling disorder, both for improving theoretical models of addictive behaviours at various stages of the addictive process, such as in the I-PACE (Interaction of Person-Affect-Cognition-Execution) model (Brand et al., 2019), and for a use in therapy with poker players with a gambling disorder. Indeed, with reference to the present study, it could be possible to explain to patients with a poker-related gambling disorder that the repeated practice of poker may not lead to the development of specific emotion identification strategies for example.

Strengths and limitations

The main strength of our research is that we investigated an understudied population with an attentional task designed to assess engagement and disengagement biases towards social-emotional information. One of the limitations of this study is that we did not follow our group over time to observe if their cognitive functioning impacted the onset of addiction or if their attentional particularities changed over time and practice. Additionally, results obtained in this study only concern live poker players. Indeed, the observation of facial expressions and nonverbal information is lacking in online poker. Moreover, there was no women included which do not permit to generalize our results to both genders. Finally, we did not control for nicotine use before the experiment, despite its dopaminergic effect.

3.1.7. Conclusions

In conclusion, our study showed particularities in social information processing associated with the regular

practice of poker. We found a higher IOR in the poker player group compared to the CG. Further research regarding the establishment of the IOR in various forms of gambling, specifically what can cause its enhancement, needs to be performed. Indeed, it would be interesting to know if this enhancement of the IOR also appears in nonsocial cues. Nevertheless, more studies are needed to explore the directionality of the link. Indeed, this study cannot conclude if poker practice led to these changes or if these particularities were displayed by the individuals before practising poker and contributed to the experimentation and maintenance of poker practice, given the advantage drawn from this specificity. Interestingly, poker players may practice their social information attention abilities

on other people in everyday life, but also specifically on other poker players, who may be bluffing and/or hiding their own social information. On the contrary, the non-players would practice these specific abilities only on everyday life situations, when people are not attempting to conceal the expression of their emotions most of the time. This specific feature of poker is an important particularity that have to be taken into account when assessing and discussing poker players' social information processing abilities. Moreover, it would be interesting to explore whether individuals with gambling disorder show a different response pattern that could be a marker between controlled and excessive practice.

Les références sont incluses dans l'annexe Références du document complet.

3.1.8. Perspectives

Cette étude a permis de démontrer que les joueurs de poker pouvaient présenter des particularités sur le plan de l'allocation de l'attention sur des stimuli sociaux, en comparaison à des sujets contrôles. L'augmentation de l'IDR peut être liée à la répétition de la pratique du poker. De manière réciproque, cette particularité cognitive et l'avantage supposé procuré peuvent avoir favorisé la pratique régulière du poker.

Ces données peuvent être utilisées auprès de joueurs de poker car elles pourraient permettre d'objectiver des stratégies mises en place par les joueurs par exemple. Par ailleurs, sur plan clinique, ces données peuvent être utilisées pour démontrer que l'augmentation des compétences en lien avec le poker reste limitée. Cette information est importante pour les cliniciens travaillant auprès de patients présentant un diagnostic de JAP et jouant au poker. En effet, les croyances dysfonctionnelles liées au poker peuvent faire penser aux patients qu'ils sont capables de gagner de l'argent en jouant, car ils ont développé des compétences particulières et notamment sur l'analyse des autres joueurs (Bouju et al., 2013). Cette étude peut ainsi être un appui pour déconstruire cette pensée pour les cliniciens.

Sur le plan des perspectives, la suite de l'étude PERHAPS a pour but de comparer les résultats des deux groupes présentés dans cet article avec les performances de patients présentant un diagnostic de JAP, concernant le poker ainsi que d'autres JHA. Ces analyses permettront de caractériser le profil de CS chez des joueurs pathologiques, en les comparant à des joueurs réguliers ou non.

Pour mieux appréhender les processus addictifs, il est ainsi important de caractériser le profil de CS de joueurs en s'intéressant, comme pour l'étude PERHAPS, aux compétences chez des personnes ne présentant pas d'addiction, mais une pratique de jeux fréquente. Ce type d'études permet d'évaluer si la présence de difficultés sur le plan de la CS est liée aux symptômes addictifs et/ou à la répétition du comportement.

Cependant, l'étude PERHAPS s'est limitée d'une part aux joueurs de poker, et d'autre part aux capacités attentionnelles en lien avec des indices sociaux. La prochaine étude avait ainsi pour but de compléter ces résultats et d'évaluer des joueurs de JHA et de JV, sur plusieurs aspects de la CS, en fonction de leur fréquence de jeu et de leur niveau d'addiction.

3.2.MANUSCRIT 4 : Evaluation en ligne des capacités de cognition sociale (CS) chez des joueurs de jeux vidéo (JV) et de jeux de hasard et d'argent (JHA)

3.2.1. Résumé en français du manuscrit 4

Cette étude a été menée auprès de la population générale dans le but de caractériser les compétences en CS en lien avec la fréquence de jeu (JHA ou JV) tout en prenant en compte la sévérité de l'addiction. En effet, nous voulions savoir si la répétition du comportement de prédilection (JV ou JHA) était liée à des particularités sur le plan de la CS ; ou si au contraire, les particularités suggérées dans la littérature concernant les capacités de CS dans les ACs étaient spécifiques à l'addiction et non liées à la répétition du comportement.

L'étude eSMILE a été menée en ligne et a permis d'inclure 105 participants (joueurs de JV et de JHA). Cette étude incluait une évaluation des capacités d'identification d'émotions faciales simples (Penn emotion recognition task – ER40), d'émotions faciales complexes (partie identification du Condensed and revised Multifaced Empathy Test – MET-CORE), de l'empathie (partie partage d'émotion du MET-CORE et Interpersonal Reactivity Index – IRI), de la prise de décision en situation sociale (CG), de la métacognition sociale et de l'alexithymie (Toronto Alexithymia Scale – TAS-20). Nous avons analysé la relation entre les performances sur les tâches de CS, les résultats aux questionnaires, le niveau d'addiction (Indice Canadien du Jeu Excessif – ICJE ; et Ten-item Internet Gaming Disorder Test – IGTD10) ainsi que la fréquence du comportement. Nous avons par ailleurs contrôlé l'impact du niveau d'alexithymie sur la performance en CS.

Pour les joueurs de JV, nous avons montré que plus la sévérité de l'addiction était élevée, plus les joueurs sous-estimaient leur performance à la tâche d'identification d'émotions simples, alors même que le fait de jouer plus était lié à de meilleures performances sur cette tâche. Par ailleurs, une dissociation entre les capacités d'identification d'émotions simples et complexes pour les joueurs de JV a été démontrée. En effet, plus ces derniers jouaient, meilleure était leur capacité de reconnaissance des visages tristes et des émotions à haute intensité, mais pire était leur performance sur les images positives plus complexes. Pour les joueurs de JHA, nous avons montré que plus le niveau d'addiction était élevé, moins la précision dans la reconnaissance des émotions faciales était bonne.

Concernant le JAP, notre hypothèse semble validée puisque la mesure d'addiction semble mieux expliquer les difficultés sur l'identification des émotions faciales que le niveau de fréquence du comportement. Pour le JVP, les résultats en lien avec la fréquence de jeu suggèrent des particularités dans le traitement des émotions faciales. De manière intéressante, c'est surtout la métacognition sociale qui semblait liée au niveau de sévérité de l'addiction.

Cette étude rappelle ainsi l'importance de multiplier les recherches, avec des outils déjà utilisés dans la littérature pour confirmer certains résultats ; mais aussi avec des outils différents pour continuer à explorer et à améliorer la compréhension de la place de la CS dans les processus addictifs. Enfin, cette recherche rappelle l'importance de la RC de la CS en tant que traitement complémentaire dans la prise en charge des patients présentant une AC.

Online assessment of social cognition in a population of gamers and gamblers: results of the eSMILE study

Elodie Hurel, Marie Grall-Bronnec, Gaëlle Challet-Bouju

3.2.2. Abstract

Background Recognition of behavioural addictions (BAs) is increasing, and two disorders have been included in international classifications: gaming disorder and gambling disorder. In these disorders, cognitive functioning is involved in the development and maintenance of addiction. Nevertheless, some cognitive functions, such as social cognition (SC), have received less attention.

Method The eSMILE study was conducted online and included 105 participants (gamers and gamblers). This study assessed the ability to identify simple (basic emotions, Penn emotion recognition task – ER40) and complex (MET-CORE identification part) emotions, empathy (Condensed and Revised Multifaced Empathy Test – MET-CORE sharing section and Interpersonal Reactivity Index – IRI), social decision-making (the Chicken Game), social metacognition, and alexithymia (Toronto Alexithymia Scale – TAS-20). We analysed the relationships among SC performance, questionnaire results, addiction levels (CPGI and IGTD10), and behaviour frequency.

Results For gamers, we showed that the higher their level of addiction was, the lower their self-confidence following the identification of basic emotions, although the more frequently they played, the better their performance on this task. A dissociation was shown, according to which the more frequently gamers played, the lower their accuracy at identifying positive pictures. Additionally, we found lower performance on the identification of more complex emotions by gamblers, which seems to be the result of their levels of addiction rather than the frequency of their gambling behaviour.

Discussion This study contributes to our understanding of the cognitive processes underlying BAs. Further research concerning patients suffering from BAs is needed, both using the same tools to confirm our results and using complementary tools to enhance our understanding of the profile of SC in the context of BAs. Additionally, working on SC abilities may be an additional management mode for BAs that could be added to existing treatments.

Key-words

Gaming disorder – gambling disorder – facial emotion identification – empathy – social decision-making – online – social metacognition

3.2.3. Introduction

Behavioral addictions (BAs)

Behavioural addictions (BAs) are nonsubstance addictions. Addiction is defined by the impossibility of controlling or stopping the behaviour and by repetition of the behaviour despite significant damage to several spheres of life (Goodman, 1990). This concept highlights a certain loss of control over a behaviour such as sport, food, sex, gaming, gaming or any behaviour that could fall into this category. Gambling disorder (GbD) was recognized as the first BA in 2013 in the fifth version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatry Association, 2013). The second BA included in international classifications of mental disorders was gaming disorder (GmD), which was included in the eleventh edition of the International Classification of Disease (ICD-11, (World Health Organization, 2018)). Several theoretical models of addiction have been proposed to understand the development and maintenance of BAs. Among these models, the Interaction Person-Affect-Cognition-Emotion (I-PACE) model includes social anxiety and loneliness as predisposing factors that may influence the development of addiction. It also includes cognitive functioning as a moderator between reactions to addiction-related stimuli and decisions to behave in certain ways. In particular, the model postulates that inhibitory control over problematic behaviour is preserved in earlier stages of addiction but gradually decreases in later stages, especially when the person in question is confronted with addiction-related stimuli (Brand et al., 2019).

Social cognition (SC)

Cognitive functioning involves different forms of cognitive abilities, including social cognition (SC) abilities. SC is an umbrella term that covers all cognitive functions that permit an individual to perceive social

information (such as the emotions displayed on faces) and thus interact and create relationships with others (Adolphs, 2001; Frith, 2008; Saxe, 2006). SC abilities include, for example, the capacity to identify facial emotions in others or abilities related to empathy (i.e., the competence to feel and understand the emotions of both others and oneself (M. Davis, 1980; Decety & Jackson, 2004)). Social decision-making is also included in the category of SC abilities and refers to the capacity to make decisions affecting oneself and other persons that depend on the decisions of both parties (Rilling et al., 2008). Another SC capacity is social metacognition, which is the ability to assess one's own abilities regarding a social object (Jost et al., 1998). Moreover, some authors have included alexithymia (i.e., the ability to identify and describe one's own emotions (Sifneos et al., 1977)) in the concept of SC (Etchepare & Prouteau, 2017). More specifically, previous research has shown that alexithymia can impact the ability to recognize facial emotions (Samur et al., 2013).

Among the various components of SC, two factors may modulate SC components: the depth of information processing (ranging from shallow to deep) and the nature of stimuli (i.e., cognitive – lacking an emotional context – or affective – with an emotional context) (Etchepare & Prouteau, 2017).

BA and SC

Despite some common neural networks between addiction and SC components and the presence of alterations of SC that have been highlighted in the context of substance use disorders (Quednow, 2020), the literature concerning BA and cognitive assessment of SC remains scarce (Hurel et al., 2019). Regarding gambling, only two studies have been conducted, which showed an alteration of nonverbal emotional processing in faces and voices in individuals with GbD (Kornreich et al., 2016) and emphasized specificities in the

attentional processing of facial cues by a group of nonproblematic poker players (Hurel, *submitted*). Moreover, research using self-report questionnaires has also shown difficulties at the psychosocial level for pathological gamblers: alexithymia seems to be a significant vulnerability factor in the development of GbD (Gori et al., 2022), and there is an association between GbD and familial difficulties (Black et al., 2012; Cowlshaw et al., 2016). Additionally, analysis of self-reported mentalization abilities has indicated a link with GbD in adolescents (Ciccarelli et al., 2021) as well as with chasing behaviour (Nigro et al., 2019).

Research focusing on GmD and SC abilities using cognitive tasks has suggested an alteration of social stimuli perception (He et al., 2019; Jiang et al., 2020; Peng et al., 2017), a lower level of cooperation (Su et al., 2018), and a link between the symptoms of GmD and the ability to infer mental states (Aydın et al., 2020). Studies linking gaming and SC have been more numerous; these studies have not indicated any difficulties in empathy, but they have reported lower levels of cooperation for nonaddicted video game (VG) players (Jin & Li, 2017). Nevertheless, the multiplicity of methodologies and populations that have been assessed in the literature do not permit any generalization of these results (Hurel, *submitted*). Additionally, self-reported level of loneliness seems to be a significant factor in the development of GmD (Paulus et al., 2018).

Thus, cognitive models, self-reports, and cognitive tasks all point in the same direction towards difficulties regarding SC abilities in the context of BA. However, more information regarding SC profiles in relation to BA could help clinicians adapt their treatments. At the scientific level, a better understanding of the cognitive features of BA can provide a better understanding of addictive processes, especially because BA offers a unique opportunity to explore the cognitive processes

involved in addictions without biases resulting from the neurotoxic effects of psychoactive substances that have been found in substance use disorder studies.

In addition, studying SC abilities in gamers or gamblers, with or without addiction, and taking into account the frequency with which they engage in specific behaviours may also help us identify the role of SC in addictive processes and thereby enlighten models of addictive processes. Indeed, this approach would permit us to determine whether SC difficulties are linked to the repetition of the behaviour or are a core characteristic of addiction via an assessment of SC competencies in nonaddicted gamers/gamblers who exhibit frequent gaming/gambling behaviour.

Objectives and hypotheses

The eSMILE (online aSSessment of social cognition of gamers and gamblers) study aimed to characterize SC abilities in a population of gamers and gamblers while taking into account their frequency of gaming or gambling and their level of addiction. This study included both self-report questionnaires and cognitive tasks to better characterize the SC profile by collecting both subjective and objective data concerning several components of SC and obtaining a unified profile of each individual (Jeong et al., 2020). We assumed that only subjects with addictive behaviour would display SC alterations. Thus, we expected to observe a significant association between higher levels of addiction, lower SC competencies, and higher self-reported difficulties. Additionally, we did not expect a significant link between SC profile and frequency of behaviour. Indeed, we did not believe that the repetition of the behaviour engenders SC alterations but rather that SC difficulties are a core characteristic of addiction. We were also interested in exploring the role of alexithymia in SC among gamblers and gamers. We expected that, when including alexithymia levels in statistical models assessing the link between SC abilities and levels of

addiction or behaviour frequency, the model including alexithymia would explain the results better than the model without alexithymia, i.e., including only levels of addiction or behaviour frequency. Indeed, high levels of alexithymia are found in GmD and GbD (Bonnaire et al., 2009; Mahapatra & Sharma, 2018), and alexithymia seems to impact the ability to process facial emotions (Grynberg et al., 2012). We wanted to control for this possible confounding variable.

Finally, this study was designed during the COVID-19 pandemic, i.e., in a period in which it was not possible to assess volunteers for research in a face-to-face format in the lab. Thus, this study aimed to evaluate the feasibility of assessing SC profiles online. Beyond the adaptation to sanitary restrictions, online studies are supposed to have the advantage of gathering more participants than usual and allowing for the better generalization of results. This approach also permits participants to retain more time and flexibility (Reips & Krantz, 2010), and it increases ecological value by allowing them to use familiar materials (i.e., their computer) in a familiar environment (i.e., not in the lab) (J. Kim et al., 2019; Reips & Krantz, 2010). It also decreases bias resulting from the experimenter's presence in the laboratory. Thus, this study included acceptability questions to assess whether participants found the instructions to be clear and whether they appreciated the online modality.

3.2.4. Method

Ethics

The GNEDS (Groupement Nantais d'Ethique dans le Domaine de la Santé) approved the protocol on 19th January, 2021. All participants consented online.

Participants

We planned to include four groups of 50 participants, two groups of gamers and two groups of gamblers, depending on their frequency of gaming or gambling.

Participants were invited to participate by email and were recruited from a registry of volunteers for research that was created by our research team or via social networks from July 2021 to April 2022.

Eligibility criteria

To be included in the study, all participants were required to (i) be at least 18 years old and less than 65 years old and (ii) have played their favourite game (gambling or VG) at least once during the 12 past months. The exclusion criteria were (i) difficulties reading or writing the French language, (ii) having used a psychoactive substance in the past 12 hours, (iii) having a neurological history (such as epilepsy, severe brain injury, neurodegenerative disease), (iv) having a diagnosis of a psychiatric or addictive disorder (with the exceptions of tobacco use disorder, gaming disorder and gambling disorder), (v) being pregnant or nursing, and (vi) being under tutelage or curatorship.

To prevent individual participants from contributing to the study twice, we asked them whether they had already participated in the experiment before allowing them to access it.

The groups were created based on the frequency with which participants had engaged in their favourite behaviour during the past three months: high-frequency groups included participants who gambled or played a VG twice per week for at least 14 hours, while low-frequency groups included participants who gambled or played a VG less than once per week. As a result, four groups were created: the low-frequency gambling group (LGB), the high-frequency gambling group (HGB), the low-frequency gaming group (LGM), and the high-frequency gaming group (HGM).

Procedure

The website Psytoolkit (Stoet, 2010, 2017) was used to host the whole experiment. Participants were informed about the study and consented to participate online

before being allowed access to the experiment. They also answered questions regarding the inclusion criteria and their frequency of gaming/gambling over the past three months to define their inclusion group.

We then collected certain information regarding sociodemographic characteristics and gambling/gaming (favourite type of gaming or gambling, duration of playing/gambling at the relevant frequency, number of hours played per month on average).

After answering these questions, participants were required to complete online cognitive tasks. Finally, they completed self-report questionnaires exploring their levels of addiction severity with respect to either gaming or gambling, alexithymia, empathy, depression and anxiety, and the acceptability of the online assessment. We also asked participants whether they had prior knowledge of the cognitive tasks and questionnaires used.

We chose to assess SC via cognitive tasks before the completion of questionnaires to avoid the effects of exhaustion and attentional decrease that may have occurred after answering all the questions.

Clinical assessment

Sociodemographic and gaming/gambling data

Sociodemographic data included age, sex, number of years of education, and living situation (alone, with family, with a partner). Gaming/gambling information included the choice of favourite game: (i) for the gambling groups, the participants could choose between poker, casino, lottery, horse race betting, sports betting, and other (free text field), while (ii) for the gaming groups, the participants could choose between First-Person Shooter (FPS), Massively Multiplayer Online Role-Playing Game (MMORPG), Sandbox, Role Playing Game (RPG), Multiplayer Online Battle Arena (MOBA) and other (free text field). Participants were also requested to indicate the name of the game they

played most frequently, the mean number of hours they played per month, and the durations for which they played at this frequency (in months).

Addiction assessment

The Canadian Problem Gambling Index (CPGI, (Ferris & Wynne, 2001)) was used to assess the addiction severity of gamblers (those who chose gambling as their favourite activity). This measure is a self-report questionnaire containing nine items regarding gambling habits during the past 12 months. Possible ratings include "never," "sometimes," "most of the time," and "nearly always". Possible scores range from 0 to 27. This tool has good specificity (Ferris & Wynne, 2001).

The Ten-item Internet Gaming Disorder Test (IGTD10) (Király et al., 2019) was used to assess the addiction severity of gamers (those who chose gaming as their favourite activity). This tool contains ten items assessing nine criteria drawn from the DSM-5 (American Psychiatry Association, 2013) and the ICD-11 (World Health Organization, 2018) with respect to the past 12 months. Possible ratings include "never," "sometimes," and "often". Possible scores range from 0 to 9. Research has indicated robust psychometric properties for this measure, which have been confirmed in several countries (King et al., 2020; Király et al., 2019).

Both questionnaires generated global scores that were used as continuous variables to indicate the level of addiction severity.

Level of depression and anxiety

The Hospital Anxiety and Depression Scale (HAD, (Zigmond & Snaith, 1983)) was used to assess levels of depression and anxiety; this measure included 14 items, which were rated from 0 to 3.

Social cognition assessment

Cognitive tasks

Cognitive tasks appeared in the same order for all subjects, as indicated below.

Penn emotion recognition task (ER-40) (C. S. Carter et al., 2009). This task aimed to assess the ability to identify simple (basic) emotions. It included forty photographs of faces (20 women and 20 men; see (Gur et al., 2002) for details regarding pictures) with respect to which the participant was required to choose between sadness, fear, joy, anger, or neutrality (for photographs not displaying any emotion). For each emotion, four high-intensity emotion pictures (with emotions expressed at a high intensity) and 4 low-intensity emotion pictures (with emotion expressed at a lower intensity) were included. The variables recorded were reaction times and the number of errors. Four randomized lists were generated to pseudo-randomize the order of presentation among participants.

Condensed and Revised Multifaced Empathy Test (MET-CORE) (Grynberg et al., 2017). This task aimed to assess the ability to identify complex emotions (by presenting pictures with a context; the emotions proposed included basic emotions and more complex emotions) and the degree of emotion sharing (a component of empathy). It included forty photographs (20 positive and 20 negative), each of which was viewed twice by the participant. In one of the presentations, the participant was required to choose the correct emotion displayed by the person in the photograph from a set of four choices. During the other presentation, participants rated the level of emotion displayed by the person in the photograph from 1 (none at all) to 9 (very strong). Regarding performance indicators, the software recorded the number of errors and reaction times for the identification questions and the rating and reaction times for the sharing component. A French team translated this task from German into French (Edele et al., 2013; Grynberg et al., 2017), which led to altered

emotion identification abilities but preserved emotion sharing in a population of patients with substance use disorder (Grynberg et al., 2017). This task was used to complement the ER-40 because it permitted the assessment of facial emotion identification abilities in response to more complex stimuli and the subsequent assessment of this SC component at both levels (simple and complex facial emotion processing).

Social decision-making: The chicken game (CG) paradigm This task was an economic game assessing the level of cooperation. In each trial, participants were required to choose between two possible choices (i.e., a cooperative choice or a noncooperative choice). The outcome of the game depended on the participant's own choice as well as on the choice of a partner in the game. In our study, the game partner was always the computer, but it was presented to the participant as either a computer (the “computer” condition) or another participant in the study (the “coplayer” condition). If both participants chose to cooperate, they both won ten points. If both participants defected, they each lost 30 points. If one cooperated and the other did not, the cooperator lost 10 points, and the noncooperator won 30 points. Matrices of payment were available to the participants throughout the task. Four trials were conducted: 2 for the “computer” condition and 2 for the “coplayer” condition (to preserve the credibility of a game played with another player, a waiting time of a few seconds was provided to simulate waiting for a connection from a coplayer). Choices (concerning whether to cooperate) made by the computer (either in the “computer” or the “coplayer” conditions) and the first condition to appear (“computer” or “coplayer”) were randomized. The software recorded choices and reaction times. In this task, the risk of defecting is more clearly identifiable than in the prisoner dilemma (another task that is often used to assess cooperation abilities). Not cooperating is the riskiest decision but

also the one in which the gains are higher (de Heus et al., 2010). This task permitted to show diminished cooperation abilities in a population of participants with GmD (Su et al., 2018).

Social metacognition. We assessed social metacognition concurrently with the other cognitive tasks: once before the completion of the task but after the instructions were provided and again after completion of the task. On a scale from 0 to 100%, participants rated their performance on the task either prospectively (before the task) or retrospectively (after the task) (T. O. Nelson & Narens, 1994). This method did not add cognitive load to the completion of the task and was intended to assess appraisal and monitoring abilities (Quiles et al., 2014).

Self-reported measures

Interpersonal Reactivity Index (IRI) (M. Davis, 1980). This questionnaire assessed empathy abilities using four scales. The Personal Distress scale (PD) reflected the ability to feel shaken or moved by someone else's distress. The Empathic Concern scale (EC) evaluated the ability to feel compassion or worry for someone. The Fantasy scale (FS) assessed the tendency to identify imaginatively with the thoughts and feelings of fictional characters. Finally, the Perspective Taking scale (PT) reflected the ability to adopt the perspective of someone else. The French version of this questionnaire was validated and demonstrated appropriate psychometrical properties (Gilet et al., 2013). In the present study, a seven-point scale with responses ranging from 1 (does not describe me well) to 7 (describes me very well) was used, as proposed in the French version of the questionnaire (Gilet et al., 2013).

Toronto Alexithymia Scale (TAS-20) (Loas et al., 1996). This questionnaire assessed the level of alexithymia and included 20 questions that were answered on a scale ranging from 1 (complete

disagreement) to 5 (complete agreement). It permitted us to calculate a global score and three subscores: difficulty identifying emotions (DIF), difficulty describing one's own emotions (DDE), and thoughts aimed at the exterior instead of internal sensations (externally oriented thinking, EOT).

Acceptability assessment

Participants were asked to answer several questions on a scale ranging from 1 (totally agree) to 5 (totally disagree) regarding the acceptability of the study. Participants were required to indicate (i) the clearness of the instructions, (ii) whether they would have visited the lab if the experiment had not been conducted online, and (iii) whether they would have preferred to meet the experimenter.

Statistical analyses

Analyses were performed using R software (version 1.25001).

The original aim of the analyses was to compare performance on SC tasks and scores on self-report questionnaires between HGB and LGB on the one hand and between HGM and LGM on the other hand to assess the relationship between the frequency of the behaviour and SC profile. Subsequently, we intended to assess the link between addiction levels and SC performance. Nevertheless, incoherent data appeared with respect to the relation between the variable assessing the mean number of hours played on average per month and the variable in the inclusion criteria that asked about the mean frequency and duration of gaming or gambling during the last three months. As questions used for inclusion were binary questions (i.e., they were answered yes or no) and because participants did not know at that time whether they would continue participating in the study, thus indicating that their levels of attention and motivation were not high at this time, we considered this variable to be less relevant. We

chose to use only the mean number of hours played per month on average as the most relevant variable for defining the frequency of the behaviour. This question was asked later, at a time when participants were more involved in the study in terms of motivation and attention. Moreover, participants were required to give a numeric answer, which requires more thinking and is thus supposed to be more reliable. Thus, we chose to keep only the analysis of the link between level of addiction and frequency of behaviour and SC measures.

In all cognitive tasks assessing reaction times (RTs), we excluded all RTs less than 250 ms because they were considered to be anticipative answers.

All correlations between variables assessing SC (self-reports and cognitive tasks) on the one hand and the mean number of hours played or addiction severity scores on the other hand were tested via Spearman correlations because these variables were not normally distributed (as determined by a Kruskal–Wallis test). For all significant correlations, several independent linear regressions with performance on the corresponding SC task as the dependent variable and the mean number of hours played or addiction severity score as the independent variable were conducted. For each regression, two models were generated, one of which included only the significant correlation between SC measures, while the other added the alexithymia score level. Both models were compared by using a likelihood ratio test, the Akaike Information Criterion (AIC), and the Bayesian Information Criterion (BIC) to select the model that best fit our data. We used this strategy to explore whether the significant correlations observed were better explained by the level of addiction or the frequency of the behaviour.

Additionally, as our objective was to separate the effect of frequency on SC performance from that of addiction, we chose to assess the effects of both variables

statistically for every variable that appeared to be correlated with level of addiction and frequency of behaviour.

When this situation appeared, we conducted a linear regression using the variable of interest as the dependent variable and the addiction severity score as the independent variable. We then added the mean number of hours played to a new model. Both models were compared by using a likelihood ratio test, the AIC, and the BIC to select the best model fitting our data.

Finally, participants' metacognitive scores were normalized using the means and standard deviations scores of all answers. Correlations between these z scores and performance on SC tasks, behaviour frequency and addiction levels were subsequently estimated.

3.2.5. Results

Descriptive analysis

Participants description

The final sample comprised 105 participants who completed the entire study; approximately half of these participants were gamers, while the other half were gamblers. Descriptive analyses of participants are provided in Table 12.

Self-reports and cognitive tasks

Descriptive statistics of self-reports and cognitive tasks are available in Tables 13 and 14.

Acceptability questions

Table 15 shows the analysis of the acceptability questions. Participants found the instructions to be clear and did not prefer to meet researchers. There was no clear preference regarding whether they would visit the lab.

Tableau 12 Sociodemographic characteristics and gaming and gambling results – Manuscrit 4

Variables	Gb	Gm
	Mean (sd) [min – max]	Mean (sd) [min – max]
Number of participants	56	49
Sociodemographic data		
Age	44.04 (12.30) [18 – 64]	31.14 (10.46) [19 – 56]
Number of males	37 (66.07%)	30 (61.22%)
Number of years studying	14.07 (3.05) [7 – 23]	15.63 (2.40) [12 – 23]
Living situation		
<i>Alone</i>	14 (25.00%)	13 (26.53%)
<i>With family</i>	24 (42.86%)	14 (28.57%)
<i>With couple</i>	14 (25.00%)	19 (38.78%)
<i>Other (mainly colocation)</i>	4 (7.14%)	3 (6.12%)
Gambling and gaming data		
Number of hours played per month	16.30 (37.39) 2 missing values [0 – 240]	54.59 (62.51) [0 – 300]
Favorite game		
<i>Poker</i>	14 (25.00%)	
<i>Casino</i>	2 (3.57%)	
<i>Lottery</i>	21 (37.50%)	
<i>Horse bet</i>	7 (12.50%)	
<i>Sport bets</i>	9 (16.07%)	
<i>Others</i>	3 (5.36%)	
<i>FPS</i>		7 (14.29%)
<i>MMORPG</i>		5 (10.20%)
<i>Sandbox</i>		2 (4.08%)
<i>RPG</i>		16 (32.65%)
<i>MOBA</i>		8 (16.33%)
<i>Other</i>		11 (22.45%)

Gb=gamblers, Gm = gamers;

Tableau 13 Descriptive statistics of acceptability questions - Manuscrit 4

Acceptability questions	Mean (sd) [min – max]
<i>Instructions were clear.</i>	1,62 (0,92) [1–5]
<i>I would not have participated if I had to come to the lab.</i>	2,64 (1,56) [1–5]
<i>I would have preferred to meet the experimenter rather than answer online.</i>	3,19 (1,43) [1–5]

Rating ranged from 1 (completely agree) to 5 (completely disagree)

Correlation analysis

Correlations between self-reports and gambling and gaming characteristics

Table 16 displays the correlations between answers on the self-report questionnaires and gambling or gaming characteristics. For both groups, we found a significant positive correlation between levels of depression and anxiety and the severity of addiction. That is, for all participants, a higher score of anxiety or depression was linked with a higher severity of addiction. Additionally, there were significant positive relationships between the addiction severity and the frequency of behaviour. That is, for all participants, the more frequently they played VGs or gambled, the more severe their addiction.

Correlations between cognitive tasks and gambling and gaming characteristics

Table 17 displays the results concerning the cognitive tasks in accordance with engagement in playing VGs or gambling games and the severity of addiction.

Regarding the ER-40 task, a significant negative correlation was demonstrated for gamers between the frequency of playing VGs and the identification of sadness, such that a higher frequency of play was correlated with a lower number of errors on sad faces and sad faces with low intensity.

Tableau 14 Descriptive statistics of self-reports - Manuscrit 4

		Gb	Gm
		Mean (sd)	Mean (sd)
		[min – max]	[min – max]
IRI			
	<i>Fantasy scale</i>	30.45 (8.87) [15–49]	34.65 (7.98) [20–48]
	<i>Personal distress scale</i>	24.38 (7.90) [9–43]	24.59 (8.18) [7–44]
	<i>Perspective taking scale</i>	31.32 (6.592302) [15–42]	35.23 (6.61) [22–49]
	<i>Empathic concern scale</i>	35.25 (6.81) [15–49]	36.98 (6.63) [16–48]
TAS-20			
	<i>Difficulty identifying emotions</i>	17.04 (5.40) [7–35]	16.39 (5.13) [7–28]
	<i>Difficulty in describing emotions</i>	14.93 (4.98) [5–25]	13.35 (4.65) [7–23]
	<i>Exterior operant thought</i>	19.21 (4.24) [8–28]	16.67 (4.43) [10–27]
HAD			
	<i>Anxiety</i>	7,68 (3.38) [3–19]	7,00 (3.83) [1–16]
	<i>Depression</i>	4.79 (2.98) [0–12]	3,53 (2.69) [0–13]
CPGI		4.36 (5.59) [0–27]	
IGTD10			1.14 (1.52) [0–7]

CPGI=Canadian Problem Gambling Index; Gb=gamblers, Gm = gamers; HAD=Hospital Anxiety and Depression scale; IGTD10=Ten-item Internet Gaming Disorder Test; IRI=Interpersonal Reactivity Index; TAS-20=Toronto Alexithymia Scale

Tableau 15 Descriptive statistics of cognitive tasks - Manuscrit 4

		Gbs	Gm
		Mean (sd)	Mean (sd)
		[min – max]	[min – max]
ER40			
Number of errors	<i>Total</i>	6,41 (3,15)	5,33 (2,13)
		[0–13]	[1–10]
	<i>Neutral faces</i>	1.34 (1.95)	0.71 (1.14)
		[0–8]	[0–5]
	<i>Angry faces</i>	2.71 (1.46)	2.14 (1.08)
		[0–7]	[0–4]
	<i>Fearful faces</i>	0.91 (1.08)	0.76 (1.11)
		[0–4]	[0–4]
	<i>Sad faces</i>	1.29 (1.40)	1.51 (1.14)
		[0–6]	[0–6]
	<i>Joy faces</i>	0.16 (0.37)	0.20 (0.46)
		[0–1]	[0–2]
	<i>Faces with low intensity</i>		
	<i>Total</i>	3.73 (1.63)	3.31 (1.37)
		[0–8]	[1–6]
	<i>Angry faces</i>	2.29 (1.00)	1,84 (0,99)
		[0–4]	[0–4]
	<i>Fearful faces</i>	0,57 (0,78)	0,43 (0,68)
		[0–3]	[0–2]
	<i>Sad faces</i>	0,8 (0,82)	0,98 (0,75)
	[0–3]	[0–3]	
<i>Joyful faces</i>	0,07 (0,26)	0,06 (0,24)	
	[0–1]	[0–1]	
<i>Faces with high intensity</i>			
<i>Total</i>	1,34 (1,55)	1,31 (1,08)	
	[0–6]	[0–4]	
<i>Angry faces</i>	0,43 (0,71)	0,31 (0,55)	
	[0–3]	[0–2]	
<i>Fearful faces</i>	0,34 (0,55)	0,33 (0,59)	
	[0–2]	[0–2]	
<i>Sad faces</i>	0,48 (0,91)	0,53 (0,71)	
	[0–4]	[0–3]	
<i>Joy faces</i>	0,09 (0,29)	0,14 (0,35)	
	[0–1]	[0–1]	
MET-CORE			

<i>Number of errors in identifying emotions</i>	12,73 (3,61) [5–20]	12,08 (2,57) [6–18]
<i>Number of errors in identifying positives emotions</i>	6,96 (1,92) [2–11]	7,24 (1,51) [5–11]
<i>Number of errors in identifying negative emotions</i>	5,77 (2,30) [1–11]	4,84 (1,65) [1–8]
<i>Reaction times during emotion identification</i>	4496,80 (1137,09) [2842–7351]	4755,30 (1174,29) [2442–8258]
<i>Rating of emotion sharing of pictures</i>	5,74 (1,45) [2–9]	5,48 (1,30) [2–8]
<i>Rating of emotion sharing of positive pictures</i>	6,37 (1,33) [1–9]	5,89 (1,39) [2–8]
<i>Rating of emotion sharing of negative pictures</i>	5,12 (1,99) [1–9]	5,06 (1,75) [1–8]
CG (A is the cooperative choice)		
<i>Number of A choices</i>	2,30 (1,26)	2,65 (1,28)
<i>Number of A choices in condition with the other player</i>	1,27 (0,77)	1,31 (0,80)
<i>Number of A choices in condition with the computer</i>	1,04 (0,83)	1,35 (0,75)
Metacognition		
<i>Metacognition before the ER-40 (2 missing values)</i>	75,98 (18,89) [5–100]	78,04 (13,77) [50–100]
<i>Metacognition after the ER-40 (2 missing values)</i>	74,15 (13,44) [40–100]	73,67 (11,11) [50–95]
<i>Metacognition before the MET-CORE (3 missing values)</i>	69,33 (14,91) [40–100]	73,60 (13,52) [50–100]
<i>Metacognition after the MET-CORE</i>	70,07 (15,27) [31–100]	67,56 (13,44) [40–90]
<i>Metacognition before the CG</i>	53,67 (17,37) [10–100]	54,52 (18,60) [10–100]
<i>Metacognition after the CG</i>	49,69 (28,06) [0–100]	54,00 (32,42) [0–100]

CG=Chicken Game; ER-40 = Penn Emotion Recognition task; Gb=gamblers, Gm = gamers; MET-CORE = Condensed and Revised Multifaced Empathy Test

Tableau 16 Correlations coefficients for self-reports - Manuscrit 4

	Mean number of hours played		Severity of addiction scores ²	
	Gb	Gm	Gb	Gm
IRI – FS	-0.05	0.21	-0.01	0.24
IRI – PD	-0.03	-0.22	-0.05	0.04
IRI- PT	-0.04	-0.03	0.02	0.01
IRI - EC	-0.20	-0.16	-0.05	0.01
TAS - DIE	0.00	-0.07	0.20	0.15
TAS - DDE	-0.06	0.21	0.19	0.23
TAS - EOT	-0.02	-0.07	-0.01	0.23
HAD - Anxiety	0,01	-0,27	0,32*	0,29*
HAD - Depression	0,17	-0,09	0,31*	0,31*
CPGI	0.55***			
IGTD10	0.40**			

$p^* = p < 0.05$, $p^{**} = p < 0.01$, $p^{***} = p < 0.001$;

CPGI=Canadian Problem Gambling Index;

Gb=gamblers, Gm = gamers; HAD=Hospital Anxiety

and Depression scale; IGTD10=Ten-item Internet

Gaming Disorder Test; IRI=Interpersonal Reactivity

Index; TAS-20=Toronto Alexithymia Scale

That is, the more frequently gamers played, the better they were at identifying sadness, specifically on pictures with low emotion intensity. Additionally, a significant negative correlation was found among gamers between the severity of gaming disorder and the identification of high-intensity faces, such that a higher level of addiction severity was correlated with a lower number of errors on extreme faces, indicating that the higher the level of addiction severity, the better gamers' ability to identify emotions on high-intensity faces.

In the MET-CORE, for gamers, there was a significant positive correlation between the frequency of behaviour and the number of errors for positive pictures. This correlation indicates that for gamers, the more hours they played, the more errors they made on positive pictures.

For gamblers, there was also a correlation between the frequency of behaviour and the number of errors on negative pictures; the more hours they played, the more errors they made on negative pictures. Additionally, the correlation between the level of addiction severity in gamblers and the number of errors on the MET-CORE was significant. That is, for gamblers, the more severe their addiction was, the more errors they made, both in total and specifically for negative pictures.

As both the frequency and level of severity were linked to the number of errors, we conducted a linear regression using the level of facial emotion identification abilities (number of errors) as the dependent variable and the addiction severity score as the independent variable. The model explaining errors and including only level of addiction demonstrated a better fit with the data than the model including both the frequency and the level of addiction. Additionally, for negative pictures (number of errors on negative pictures), the model including both frequency and addiction better explained our results than the model including only addiction, and both models provided better explanations than the model that included only the frequency of behaviour.

No link was found between gaming or gambling habits and empathy-sharing responses.

Finally, regarding the CG task, no analysis of correlation reached significance; see Table 17 for the specific numbers.

Metacognitive scores and correlations between performance on tasks and gambling and gaming characteristics

Normalized metacognitive scores (z scores) both before (pretask) and after (posttask) the cognitive tasks were linked with several variables; see Tables 18 and 19 for the results.

Tableau 17 Correlation coefficients for cognitive tasks - Manuscrit 4

	Coefficient of correlation with mean number of hours played		Coefficient of correlation with scores on addiction questionnaires	
	Gb	Gm	Gb	Gm
ER-40				
Number of errors				
<i>Total</i>	-0,12	-0,04	0,10	-0,15
<i>Neutral faces</i>	-0,13	0,19	0,17	0,12
<i>Angry faces</i>	-0,143	-0,012	-0,068	-0,163
<i>Fearful faces</i>	0,21	-0,06	0,11	0,01
<i>Sad faces</i>	0,00	-0,34*	0,12	-0,23
<i>Joyful faces</i>	0,05	0,01	0,16	-0,05
Faces with low intensity emotion				
<i>Neutral faces</i>	-0,01	-0,17	-0,01	-0,11
<i>Angry faces</i>	-0,16	0,09	-0,10	-0,06
<i>Fearful faces</i>	0,21	-0,11	0,09	0,03
<i>Sad faces</i>	-0,11	-0,32*	-0,08	-0,06
<i>Joyful faces</i>	0,08	0,06	0,25	-0,14
Faces with high intensity emotion				
<i>Total</i>	0,03	-0,14	0,17	-0,34*
<i>Angry faces</i>	-0,04	-0,11	0,01	-0,18
<i>Fearful faces</i>	0,12	0,04	0,04	-0,14
<i>Sad faces</i>	-0,02	-0,20	0,22	-0,24
<i>Joyful faces</i>	-0,01	0,05	-0,03	0,06
MET-CORE				
Number of error total	0,23	0,28	0,40**	0,04
Number of errors for positive emotions	0,12	0,32*	0,25	0,07
Number of errors for negative emotions	0,28*	0,13	0,45***	0,02
Emotion sharing rating, global	0,12	0,01	0,11	-0,04
Emotion sharing rating, positive	0,08	0,14	0,09	-0,02
Emotion sharing rating, negative	0,12	-0,05	0,14	-0,04
CG				
Number of A choices total	0,07	-0,02	0,07	0,06
Number of A choices in the coplayer condition	0,03	0,03	0,10	0,03
Number of A choices in the computer condition	0,09	-0,07	0,04	0,05

$p^* = p < 0.05$, $p^{**} = p < 0.01$, $p^{***} = p < 0.001$; CG=Chicken Game; Gb = gamblers, Gm = gamers; ER-40 = Penn Emotion Recognition task; MET-CORE = Condensed and revised Multifaced Empathy Test; RT= reaction time

First, there was a significant negative relationship between the number of errors on positive pictures made by gamblers in the context of the MET-CORE and their pretask metacognitive scores. Indeed, the more mistakes gamblers made, the less confident they were before the task.

There was a significant positive correlation for gamers between posttask metacognitive scores in the MET-CORE and ratings, specifically for negative pictures. This correlation indicates that, for gamers, the higher the level of emotion sharing rating with all pictures, specifically by negative pictures, the higher their level of confidence after the task.

Regarding the CG, for gamblers, there was a significant correlation between both pretask and posttask metacognitive scores and the number of cooperative choices with the other player. Before the task, this correlation was positive, indicating that the higher the participants' levels of confidence before the task were, the more they cooperated with the "coplayer". After the task, this correlation was negative. That is, the higher their levels of cooperation with the other person were, the lower their levels of confidence after the task.

Regarding the CG, for gamblers, there was a significant correlation between both pretask and posttask metacognitive scores and the number of cooperative choices with the other player. Before the task, this correlation was positive, indicating that the higher the participants' levels of confidence before the task were, the more they cooperated with the "coplayer". After the task, this correlation was negative. That is, the higher their levels of cooperation with the other person were, the lower their levels of confidence after the task.

In the analysis of correlations between the pretask or the posttask metacognitive z scores and the frequency of the behaviour, no correlation reached significance. For gamblers, there was a positive and significant

correlation between the level of addiction severity and pretask metacognition in the CG. This relationship indicates that the higher the participant's addiction severity was, the higher that participant's level of confidence regarding his or her performance on the CG.

For gamers, a negative and significant correlation was found between levels of addiction severity and posttask metacognitive scores on the ER-40 task ($r=-0.31$, $p=0.04$). This relationship indicates that for gamers, the more severe their addiction, the lower their confidence regarding their performance on the ER-40 task.

Regression analysis

All significant correlations were tested using a linear regression with or without alexithymia global score as a covariate, but only one model including alexithymia fit the data better than the simpler model (p value of models, LRT and AIC, and BIC are available in the supplementary material). The only SC component that was better explained by the model including the level of alexithymia was the model used to explain the posttask metacognitive score on the MET-CORE for gamers. Indeed, the model including the rated level of emotion sharing did not explain the data better than the model including both the rated level of emotion sharing and the level of alexithymia. That is, the metacognitive assessment of the ability to share an emotion is linked to the rating level as well as to the level of alexithymia.

3.2.1. Discussion

The eSMILE study aimed to characterize SC abilities in accordance with gaming and gambling frequency using cognitive tasks and self-reports. We chose the online modality to (i) prevent people from moving during the pandemic and (ii) assess the possibility of evaluating SC online. We included more than 100 participants in this study.

Tableau 18 Correlation between metacognitive scores and performance on cognitive tasks - Manuscrit 4

Cognitive variables included in the correlation	Coefficient of correlation with the z score of the metacognitive score before the task		Coefficient of correlation with the z score of the metacognitive score after the task	
	Gb	Gm	Gb	Gm
ER-40				
Number of errors total	-0,02	0,14	-0,12	-0,12
Number of errors for faces with low intensity	0,04	-0,02	0,16	-0,04
Number of errors for faces with high intensity	0,02	0,22	0,03	-0,16
MET-CORE				
Number of errors total	-0,23	0,15	0,09	-0,18
Number of errors for positive pictures	-0,28*	0,16	-0,03	-0,13
Number of errors for negative pictures	-0,16	0,14	0,16	-0,12
Rating total	0,19	-0,12	-0,07	0,41*
Rating for positive pictures	-0,01	-0,01	-0,01	0,26
Rating for negative pictures	0,23	-0,19	-0,07	0,40*
CG				
Number of cooperative choices	0,23	0,01	-0,09	0,35*
Number of cooperative choices in the coplayer condition	0,44**	0,15	-0,29*	0,19
Number of cooperative choices in the computer condition	-0,05	-0,14	0,16	0,30*

$p^* = p < 0.05$, $p^{**} = p < 0.01$, $p^{***} = p < 0.001$. CG=Chicken Game; ER-40 = Penn Emotion Recognition task, Gb= gamblers; Gm = gamers; MET-CORE = Condensed and revised Multifaced Empathy Test

Tableau 19 Correlations between metacognitive scores and gaming and gambling characteristics - Manuscrit 4

	Number of hours played		Level of addiction	
	Gb	Gm	Gb	Gm
Metacognitive score before the ER-40	-0,02	-0,15	-0,04	-0,21
Metacognitive score after the ER-40	0,10	-0,05	0,04	-0,31*
Metacognitive score before the MET-CORE	-0,25	-0,14	-0,18	0,08
Metacognitive score after the MER-CORE	-0,14	0,01	0,05	-0,08
Metacognitive score before the CG	0,18	0,13	0,27*	0,22
Metacognitive score after the CG	-0,08	0,06	-0,06	0,11

$p^* = p < 0.05$, $p^{**} = p < 0.01$, $p^{***} = p < 0.001$, CG=Chicken Game; Gb= gamblers; Gm = gamers; ER-40 = Penn Emotion Recognition task, MET-CORE = Condensed and Revised Multifaced Empathy Test

Regarding self-reports, the analysis showed that the more severe a person's addiction was, the higher that person's levels of anxiety and depression. Additionally, self-reported measures of empathy and alexithymia were not linked with the severity of addiction or the frequency of the behaviour.

Using cognitive tasks, we found a dissociation between simple and complex facial emotion identification abilities for gamers. For gamblers, this study found a negative link between the ability to identify a facial emotion and the level of addiction severity. Regarding social metacognition, particularities emerged for both groups regarding their assessments of facial identification abilities and levels of cooperation.

Gamers' ability to identify facial emotions and metacognitive abilities

As discussed above, we showed that the more frequently gamers played, the better they were at identifying sadness; the more severe their addiction was, the more accurate they were in identifying simple and highly intense facial emotions. These results are contrary to our expectations, even if research has shown that GmD subjects engage in a specific form of unconscious processing of emotional faces in the context of a population of patients with GmD (He et al., 2019; Peng et al., 2017). These studies did not assess the ability to correctly identify a facial emotion. Our results may also be linked with the fact that playing VGs may enhance cognitive functioning (Bediou et al., 2018). Indeed, playing VGs may improve the ability to efficiently process visual cues and may have thus helped our participants answer more accurately when identifying basic facial emotions as a result of this training.

Interestingly, we also showed that the more frequently gamers played, the lower their accuracy in identifying positive emotions in complex pictures. This finding

may seem to contradict the results mentioned above. Nevertheless, those results were obtained in the context of a more complex task and may suggest that emotion processing is facilitated by playing VGs in the context of responding to simple stimuli but not complex stimuli. This dissociation is possible and has been demonstrated in individuals on the autism spectrum without an intellectual disability with respect to simple and complex prosody identification (Icht et al., 2021).

However, our study remains exploratory and does not permit us to make specific conclusions regarding the dissociation between simple and complex facial emotion identification. To answer this question, we would need to compare participants with a high frequency and a low frequency of gaming and control for addiction severity on a task such as the Reading the Mind in the Eyes Test. Indeed, this task comprises pictures that include only eyes, to which participants must attribute a complex emotional state. One study showed that the level of performance on this task with respect to negative emotions in among students might predict the severity of GmD (Aydin et al., 2020).

Contrary to our hypothesis, we did not find any link between the level of addiction and accuracy in identifying simple or complex facial emotions in gamers. This finding could be linked to our sample's low level of addiction and the fact that they were not seeking treatment. Our sample did not represent patients in a clinical setting who faced with social difficulties. It would be interesting to use the ER-40 and the MET-CORE to investigate treatment-seeking patients to confirm the absence of any alteration in the ability to identify a facial emotion in the context of GmD while continuing to use self-reports to control for alexithymia because this ability impacts facial emotion processing (Grynberg et al., 2012).

Interestingly, the analysis of the metacognitive scores after the ER-40 task (assessing basic emotion recognition) showed that the higher gamers' levels of addiction were, the lower their estimations of their performance. Our results suggest that pathological gamers tend to underestimate their ability to identify social stimuli. Metacognitive skills were proven to be deficient in a group of patients with cocaine use disorder (Balconi et al., 2014) and patients with Parkinson's disease and GbD compared to patients with Parkinson's disease but without GbD (Angioletti et al., 2020). In both studies, participants completed the Iowa Gambling Task (a decision-making task under conditions of uncertainty (Bechara, 2005)) and were required to estimate their performance on this task. These results suggest that addiction may be linked to a global deficit in metacognition. Indeed, our results showed that in cases of GmD, social metacognition might be altered. Nevertheless, further studies are needed to determine whether this tendency to underestimate one's performance exists in the context of other tasks. If a deficit in metacognition appears in regard to several cognitive functions, this deficiency would be a common trait among cases of GbD, cocaine use disorder, and GmD. In this situation, metacognition deficits would be linked to addictive processes rather than the ingestion of psychoactive substances.

Gambler's ability to identify facial emotions

As discussed above, we showed that, for gamblers, the more frequently they played or the higher their level of addiction, the lower their accuracy in identifying complex negative emotions. These results seem to indicate that the errors made by gamblers may be linked to addiction rather than the frequency of the behaviour. Additionally, we controlled for alexithymia level and

showed that these difficulties were not linked to this factor.

Using this framework, one study showed an alteration of emotion identification abilities in GbD patients with respect to both faces and voices (Kornreich et al., 2016). Thus, the research of Kornreich et al. and our study both suggest that SC, specifically the ability to identify emotions, is impaired in this context. Further studies comparing high frequency, low frequency, and GbD patients must be conducted to confirm this hypothesis. Indeed, we must investigate whether these difficulties may be linked more closely with a certain type of emotion (negative, positive ones) and whether other abilities are impaired. Actually, if facial emotion recognition is altered in cases of GbD, this situation could lead to other deficits because this type of information is used when inferring mental states (theory of mind, (Premack & Woodruff, 1978)) (Achim et al., 2020). This type of difficulty would explain some of the difficulties that have reported by patients regarding familial difficulties, for example (Black et al., 2012).

Additionally, this component could be a target in therapies. Indeed, the use of cognitive remediation may help patients deal with social difficulties and enhance their social functioning (Kurtz et al., 2016; Kurtz & Richardson, 2012). This approach would lead to improving the social sphere, which is important in cases of addiction (H. S. Kim & Hodgins, 2018).

Social decision-making

No significant relationships were found when assessing levels of cooperation in the social decision-making task. Some people indicated that they were familiar with the dilemma (even if they identified it as the prisoner dilemma instead of the CG). We decided to remove the scores of participants who were familiar with the prisoner's dilemma (n=4) to determine whether those participants may have biased our results. Nevertheless,

the correlations among the number of cooperative choices, behaviour frequency, and levels of addiction remained nonsignificant.

Regarding the link with social metacognition, the higher gamblers' levels of addiction severity were, the more confident they were before the CG. Nevertheless, level of addiction severity was not correlated with more cooperative choices. Additionally, the metacognitive scores of gamers tended to correlate with their behaviour towards the computer, while the metacognitive scores of gamblers tended to correlate with their levels of cooperation with the other player. A study of GmD subjects using the CG showed that participants with GmD tended to vary in terms of their level of cooperation depending on the partner with whom they were playing (Su et al., 2018). Even if we did not find that more cooperative choices were linked with addiction in one condition or the other, we can assume that gamers attributed their success to the fact that they cooperated with the computer, while gamblers anticipated that cooperation with the other player would be a good performance. Further research is needed to investigate the profiles of cooperation using different methods (more trials, different stories), but preserving both conditions seems important.

Empathy abilities in BA

No significant relationships were found between behaviour frequency or addiction and empathy measures using self-report and cognitive tasks. These results suggest the preservation of this ability, as has been found in the context of alcohol use disorder using the MET-CORE (Grynberg et al., 2017) and suggested by tasks completed by participants without GmD (Ferguson & Colwell, 2020; Gao et al., 2017b; Kühn et al., 2018b; Miedzobrodzka, van Hooff, et al., 2021; Szycik, Mohammadi, Munte, et al., 2017). Nevertheless, lower empathic abilities have been reported with IRI in a GbD population (Tomei et al.,

2017). Thus, further studies are needed to confirm the presence of empathy alterations in GbD by assessing a population of treatment-seeking patients. It is also necessary to assess the attribution component of empathy using another task, such as the Levels of Emotional Awareness Scale (LEAS (Lane et al., 1990)). This scale demonstrated a lower level of emotional awareness in a population of substance use disorder patients (Carton et al., 2010). Using this task in the context of GbD and GmD patients may be a way of highlighting the dissociation between the BAs with respect to this SC component. This approach would permit the adaptation of treatment depending on the features of each BA.

The online experimentation

We wanted to assess the possibility of conducting such studies online. Our conclusions regarding this experiment are mixed. Indeed, our statistical plan was affected by instances in which inclusion criteria were not respected. This situation would not have happened if we had checked these criteria by phone, for example. Additionally, we encountered some difficulties regarding the number of inclusions. Indeed, while we planned to recruit 200 participants, we ultimately only recruited 105 over nine months. Throughout the duration of this study, we understood that it would have been easier to conduct this study via smartphone because many people do not have access to a computer, and diffusion via social media would have been facilitated. Moreover, including a reward for participation (such as a prize or gift certificate) could have increased participation and motivation.

However, the acceptability questions showed that participants might prefer not to meet the experimenter, thus suggesting that online participation may be easier. Our conclusion is that our methodology can be improved, specifically with respect to the construction

of the task (accessibility on smartphones, prior confirmation of inclusion criterion).

3.2.2. Conclusion

The eSMILE study showed that gamers and gamblers might present different difficulties with respect to SC. Indeed, gamers' level of addiction can be linked with difficulties in assessing their own social abilities. GmD

seems to be linked with difficulties identifying complex facial emotions. Our analyses found no effects of addiction or behaviour frequency on social decision-making and empathy. Assessing and improving SC abilities may be an alternative management mode for BAs that could be added to usual treatments, as in the case of one patient with sexual addiction (Hurel et al., 2021)..

Les références sont incluses dans l'annexe Références du document complet.

3.2.3. Perspectives

Cette étude a permis ainsi de caractériser le profil des compétences en CS d'un échantillon de joueurs issus de la population générale en fonction de la fréquence de jeu et du niveau d'addiction. Les capacités de reconnaissance des émotions faciales simples et complexes, d'empathie, de prise de décision en situation sociale ainsi que de métacognition sociale ont été évaluées et mises en lien avec les mesures d'addiction, mais aussi de fréquence de jeu.

Cette recherche permet de faire le lien entre la sévérité de l'addiction, la fréquence de jeu et les compétences en CS, mais d'autres études sont encore nécessaires pour pouvoir caractériser finement le profil de CS dans une population de patients présentant un diagnostic d'AC. En effet, les participants de l'étude eSMILE étaient issus de la population générale. Les niveaux de sévérité de l'addiction, et donc de difficultés ou d'altération, pouvaient être moindres par rapport à ceux qui peuvent être exprimés par des patients en clinique. Cette caractéristique de la population ne reflète donc pas exactement le profil des patients rencontrés en clinique.

Il est ainsi important d'évaluer les capacités de CS pour des patients issus d'une population clinique et ainsi compléter les résultats obtenus dans les deux manuscrits précédents en explorant ces compétences dans une population avec un diagnostic d'AC. La recherche qui suit a été menée au sein du service d'addictologie du CHU de Nantes, dans le but de répondre à ces questions.

3.3.MANUSCRIT 5 : Protocole des études BANCO et BANCO2 et résultats préliminaires de l'évaluation de la cognition sociale chez des patients présentant un diagnostic de jeu d'argent pathologique

3.3.1. Présentation de l'étude BANCO et résumé en français du manuscrit 5

L'objectif des études BANCO et BANCO2 est d'investiguer le profil neurocognitif de patients présentant des ACs variées et d'établir des parallèles entre les différentes formes d'ACs pour construire un concept commun d'addiction. Cette étude a démarré en même temps que ce travail de thèse, dans le service de recherche de l'IFAC (Institut Fédératif des Addictions Comportementales) au sein du CHU de Nantes, et continuera jusqu'en novembre 2022 au minimum. Les études BANCO et BANCO2 partagent la même méthodologie, la différence se situant sur l'AC étudiée (BANCO portant sur les patients avec un diagnostic de JAP, BANCO2 portant sur des patients présentant une addiction sexuelle (AS), une addiction à l'alimentation (AA) ou un diagnostic de JVP).

Le manuscrit 5, qui est résumé ici, pose le cadre théorique à cette étude, et en présente tous les aspects méthodologiques.

L'étude BANCO a pour but d'inclure 30 sujets avec un diagnostic de JAP, tandis que l'étude BANCO2 a pour objectif d'inclure 30 individus avec un diagnostic de JVP, 30 sujets présentant un diagnostic d'AS et 30 sujets avec un diagnostic d'AA. De plus, pour chaque groupe d'AC, 30 volontaires sains appariés sur le sexe, l'âge, et le niveau d'étude seront inclus.

L'évaluation neuropsychologique permet de mesurer les capacités attentionnelles (avec ou sans objet de l'addiction), de sensibilité à l'interférence, de planification, de visuo-construction, d'inhibition, de CS, de prise de décision et de flexibilité. Le niveau pré-morbide d'intelligence est aussi contrôlé grâce au fNART (French Version of the National Adult Reading Test, (Nelson, 1982)). La sensibilité aux indices et les réponses physiologiques, tout comme des données cliniques sur les caractéristiques de l'addiction et la personnalité sont aussi recueillies.

Concernant plus particulièrement l'évaluation de la CS, les sujets sont évalués grâce à la mini-SEA (Bertoux et al., 2012). Cette mini-batterie inclut une tâche de reconnaissance des émotions faciales simples, ainsi qu'une tâche de faux-pas (10 histoires dans lequel le participant doit déterminer si un protagoniste a commis une maladresse sociale) évaluant les capacités de TdE. Cette tâche a l'avantage d'évaluer grâce aux sous-scores les capacités d'identification d'un faux-pas, de compréhension, d'attribution d'intention, d'attribution de croyance et d'émotion.

A la fin de l'étude, un score composite basé sur les tâches cognitives sera calculé grâce à une analyse en composante principale (ACP). La performance globale cognitive et les détails de chaque performance sur les différentes tâches cognitives seront comparés entre individus avec une AC et avec leurs contrôles

appariés en utilisant un modèle linéaire avec des effets aléatoires. Les comparaisons seront aussi effectuées entre les groupes d'AC pour investiguer les altérations spécifiques à chaque trouble.

Les résultats de ce programme vont impacter la recherche mais aussi la clinique en (i) fournissant de nouvelles connaissances pour les discussions concernant l'inclusion de certaines ACs sous le spectre des troubles addictifs, (ii) en améliorant la compréhension des mécanismes addictifs en général, (iii) en procurant des informations sur les zones grises de la recherche dans les ACs et en améliorant la compréhension des ACs les moins étudiées, (iv) en guidant les cliniciens pour proposer des alternatives thérapeutiques et programmes complémentaires.

Les résultats préliminaires de l'étude BANCO concernant les patients avec un diagnostic de JAP sont présentés à la suite de l'article.

A Case–Control Study on Behavioral Addictions and Neurocognition: Description of the BANCO and BANCO2 Protocols

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3.3.2. Abstract

Introduction Only two behavioral addictions (BAs) are currently recognized in international classifications (gambling disorder: GbD; gaming disorder: GmD), while some of them await further investigation (food addiction: FA; sexual addiction: SA). Neurocognitive functioning is considered a risk factor for BAs. Research is quite abundant for GbD and highlights specific deficits in several cognitive functions. Nevertheless, grey areas still exist. The aim of this research programme is to investigate the neurocognitive profiles of patients presenting with various BAs and to establish parallels between different forms of BA to achieve a common addiction concept.

Methods and Analysis This research program is composed of two studies sharing the same methodology but focusing on different samples: the BANCO study aims to include 30 individuals with a GbD, whereas the BANCO2 study aims to include 30 individuals with a GmD, 30 with a SA, and 30 with a FA. Moreover, for each BA group, 30 healthy controls will be recruited, matched by sex, age and education level. Several cognitive tasks will be completed by participants. Cue reactivity and physiological responses, as well as clinical data regarding addiction characteristics and personality, will also be investigated. A composite score based on the cognitive tasks will be computed using principal component analysis (PCA). Overall cognitive performance and detailed performance on the different cognitive tasks will be compared between individuals with BAs and their matched healthy controls using linear models with random effects. Comparisons will also be made between BA groups to investigate specific alterations associated with each disorder.

Discussion The results of this research program will impact both research and clinical areas by (i) providing new knowledge for discussions regarding the inclusion of BAs under the spectrum of addictive disorders; (ii) improving understanding of addiction mechanisms in general; (iii) providing clarity in the grey areas in neurocognitive research on BAs and improving the understanding of less studied BAs, (iv) guiding clinicians to propose therapeutic alternatives and complementary programs.

Trial Registration: BANCO study (ClinicalTrials.gov NCT03202290); BANCO2 study (ClinicalTrials.gov NCT03967418).

Keywords Behavioral addiction – neurocognition – neuropsychology – gaming disorder – gambling disorder – sexual addiction – food addiction

3.3.3. Introduction

Background and rationale

Behavioral Addictions

Behavioral addictions (BAs) are non-substance addictions. The object of addiction can, therefore, be a sport, food, sex, gambling, gaming, or any behavior that could produce pleasure and provide relief from internal discomfort that is employed in a pattern characterized by (i) recurrent failure to control the behavior (powerlessness) and (ii) continuation of the behavior despite significant negative consequences (unmanageability) (Goodman, 1990).

Regarding the actual recognition of BAs, international manuals of mental diseases recognize only two of them. The first BA to be acknowledged was gambling disorder (GbD) in the “Substance-related and addictive disorders” section of the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM) in 2013 (American Psychiatry Association, 2013). The classification in the tenth edition of the International Classification of Disease (ICD-10) went from an impulse-control disorder to an addictive behavior in the ICD-11 in 2018. The second BA, gaming disorder (GmD), was defined more recently in 2018 in the ICD-11. Other pathological behaviors are often reported as BAs in the literature, such as sexual addiction (SA) (Goodman, 2001), food addiction (FA) (Hebebrand et al., 2014; Meule, 2015), excessive exercise (Chen, 2016), kleptomania (Cuzen & Stein, 2014), or shopping addiction (Hussain et al., 2015). Recently, SA (M. D. Griffiths, 2016; Kraus et al., 2016) and FA (Hebebrand et al., 2014; Schulte et al., 2017) have been under particular investigation regarding whether they should be considered BAs. However, the level of evidence is still too poor, and further research is needed.

Regarding SA in particular, the lack of evidence rather than contradictory pieces of evidence seems responsible for this lack of acknowledgement (Chamberlain &

Grant, 2019). The ICD-11 included “compulsive sexual behavior disorder”, which has a prevalence rate of 2.0 to 3.7% in the general population (Chamberlain & Grant, 2019), within the “Impulse-control disorder” section. This disorder is still awaiting further investigation regarding the mechanisms of its development and maintenance before it can be included in the addiction section (Kraus et al., 2018). Symptoms presented in the ICD-11 include (i) sexual activities as the main interest, which leads to neglect in other spheres, (ii) recurrent failures to control or diminish sexual activities, (iii) continuation of the behavior despite negative consequences, (iv) persistence of the behavior even if there is no satisfaction from it, (v) persistence during a prolonged period of time and (vi) negative impacts in different spheres of daily functioning (Kraus et al., 2018; World Health Organization, 2018). There have been some arguments in the literature to consider SA in the framework of an addictive disorder rather than an impulse-control disorder (Goodman, 2008). First, literature reviews of human studies have suggested that people with SA experience withdrawal symptoms (such as anxiety or depression), tolerance (increase in the behavior) and difficulties stopping the behavior (Garcia & Thibaut, 2010; Kühn & Gallinat, 2016). Second, similar to addictive symptoms, it has been shown that patients with unregulated use of pornography display higher self-reported cognitive impulsivity and higher levels of craving than recreational and frequent users of pornography (Antons et al., 2019). Third, the exploration of patterns of cerebral activation during viewing of explicit sexual videos (Gola et al., 2017) and during performing an incentive delay task with explicit sexual stimuli (Voon et al., 2014) showed increased striatal activation in a group of problematic users of pornography compared to controls, supporting the idea that sexual cues are more salient for problematic users of pornography. Taken together, neuroimaging studies

of people with compulsive sexual behavior showed a similar pattern of activation to patients with addiction, specifically in networks implicated in cue reactivity (Kowalewska et al., 2018). Finally, even if international classifications have not yet classified compulsive sexual behavior disorder as an addiction, clinicians have already proposed some treatments recognized as effective in the field of addiction, such as cognitive behavioral therapy and motivational interviewing (Leppink & Grant, 2016). Pharmacological treatments, such as naltrexone, which is known to inhibit dopamine release in the ventral part of the striatum and is used as a treatment to regulate craving in alcohol use disorder, have been used with patients with a compulsive sexual behavior disorder and resulted in improvements in their symptoms (Leppink & Grant, 2016; Raymond et al., 2010; Verholleman et al., 2020). These arguments are thus in favour of considering compulsive sexual behavior disorder as a BA, which could permit the expansion of alternative treatments and research, thereby providing benefit to patients (Potenza et al., 2017).

The concept of FA emerged during the previous century, but human research has primarily emerged in the last decade (Meule, 2015). This concept is based on the model of substance use disorder as proposed in the DSM (American Psychiatry Association, 2013). Indeed, FA reflects the idea that food can be considered addictive and can trigger addictive behavior such as (i) ingestion of a larger amount of food than was intended, (ii) constant desire or repetitive failure to stop the behavior, (iii) recovery from or engagement in the behavior occupies much time, (iv) withdrawal from daily life spheres, and (v) repetition of the behavior despite negative consequences (American Psychiatry Association, 2013; Corsica & Pelchat, 2010; Imperatori et al., 2016; Meule & Gearhardt, 2014). Its classification as a BA remains under discussion because the ingestion of food can be likened to the ingestion of

substances, while the behavior of eating itself can be considered the BA (Corsica & Pelchat, 2010; Meule & Gearhardt, 2014; Schulte et al., 2017). FA can be evaluated with the Yale Food Addiction Scale (YFAS (Gearhardt et al., 2009)), which is a 25-item questionnaire that assesses eating habits within the last 12 months and is based on the DSM-5 criteria for substance use disorder (American Psychiatry Association, 2013). Using this questionnaire, research found a prevalence of FA ranging from 1.7% to 8.8% in non-clinical samples from European countries (Imperatori et al., 2016). In clinical samples, the prevalence is higher and can reach up to 95.7% in patients diagnosed with binge eating disorder (de Vries & Meule, 2016), 60% in patients with anorexia nervosa, 81.5% in patients with bulimia nervosa and 72.2% in patients with an eating disorder not otherwise specified (Granero et al., 2014). A systematic review of research in bulimia nervosa showed that FA plays a role in the maintenance of bulimia nervosa symptoms (Leslie et al., 2019). Moreover, in bulimia nervosa, the lower the FA severity is, the better the short-term prognosis after a brief psychoeducation group session (Hilker et al., 2016). In summary, FA can be found in individuals with any eating disorder but still needs to be explored to determine whether it can be considered a diagnostic entity itself or a transdiagnostic symptom among eating disorders (Corsica & Pelchat, 2010; Imperatori et al., 2016). Regarding neuronal activity patterns, higher FA scores in a non-clinical sample were correlated with higher neuronal activation in the anterior cingulate cortex, medial orbitofrontal cortex and amygdala in anticipation of palatable food cues, suggesting a link between FA and motivational networks (Gearhardt et al., 2011). To our knowledge, such an investigation has not been performed in clinical samples of patients with FA, but it seems that reward processing circuits are altered in patients with eating disorders (Kalon et al., 2016). For example, obese individuals compared to

controls display altered striatal dopamine functioning (Lindgren et al., 2018; Wang et al., 2001) and higher activation of motivational networks when looking at high-calorie food (Corsica & Pelchat, 2010; Stoeckel et al., 2008). Additionally, patients with binge eating disorder or bulimia nervosa exhibited higher food cue reactivity than controls without an eating disorder (Meule et al., 2018). Therefore, this body of evidence suggests alterations in the neuronal circuits involved in reward and motivational processes, as found in substance use disorder patients (Lindgren et al., 2018). Furthermore, a review of the literature on animal studies exploring food addiction also supports the classification of FA as an addiction by showing neurobiological changes in rodents when exposed to high-fat or highly palatable food (Gordon et al., 2018).

Considering their shared characteristics with other BAs and substance use disorder, there are strong arguments, especially clinical arguments, that SA and FA could be considered BAs (H. S. Kim & Hodgins, 2018).

Cognitive Functioning in Addictions

The Interaction of Person-Affect-Cognition-Execution (I-PACE) model (Brand et al., 2019; Brand, Young, et al., 2016) postulates that addiction is a multistep process. During the first step, external and internal triggers lead to affective or cognitive responses that guide the decision to realize the behavior to produce gratification or relief. The repetition of the behavior combined with individuals' characteristics progressively modifies the response to external and internal triggers, leading to the facilitation of craving and a loss of control over the behavior. Such changes are increased by deficits in cognitive control over stimuli related to problematic behaviors. The search for gratification gradually turns into the search for compensation, and biases in coping styles and cognition participate in the maintenance of problematic behaviors.

Thus, factors that influence the loss of control over urges are central to understanding the mechanisms underlying addictions and can be leveraged to achieve recovery in treatment approaches. Among those factors, cognitive functioning may play a central role in the loss of "willpower" (Bechara, 2005). Indeed, the triadic neurocognitive model of addiction (Noël et al., 2013) postulates that the loss of control over addictive behaviors is the result of an imbalance between three key interacting cognitive systems. The impulsive system processes automatic functions dealing with routine situations and salient behaviors through the amygdala-striatum network. The reflective system handles decision making in new and more complex situations through two executive networks: (i) frontostriatal and frontoparietal networks deal with cool executive functions that handle basic executive functioning without an influence of emotions, while (ii) the ventromedial prefrontal cortex mediates hot executive functions that trigger emotional states based on memories and knowledge. Finally, the interoceptive system, which involves the insula, modulates the interplay between the first two systems. This system is in charge of translating physiological information into feelings, and therefore, it would be implicated in craving and urges (Noël et al., 2013). According to this model, addiction is the result of an imbalance in the interactions among the three systems. The reflective system would be hypo-activated, leading to impaired control and undervaluation of future consequences, while the impulsive system would be hyper-activated, triggering hyper-salience to addiction-related cues. Finally, the interoceptive system would allocate more resources to the hyper-activated impulsive system, thus favouring addiction-related cues, at the expense of the reflective system, leading to the loss of willpower (Noël et al., 2013; Wei et al., 2017).

Research regarding cognitive functioning in patients presenting with a BA has mainly been developed in the field of GbD. Indeed, GbD patients were found to show impairments in risky decision making (Ciccarelli et al., 2017), especially in the context of uncertainty (Balodis, 2020). Regarding inhibitory control, ie, the ability to stop an already programmed action (C. M. MacLeod, 2007), analysis of the literature highlighted deficits in a large panel of tasks such as the go-nogo task, stop-signal task (SST) and Stroop task (Chowdhury, 2017; Ioannidis et al., 2019). Regarding flexibility, ie, the ability to adapt behavior or a strategy in the face of a change in the environment (Miyake & Friedman, 2013), the results have not converged, and further study is required (Rochat et al., 2019). A review of the literature showed that attentional processes also seem to be biased, with an attentional bias towards gambling cues highlighted in GbD patients (Hønsi et al., 2013). Additionally, some cognitive functions, such as social cognition (ie, all functions that permit the development and maintenance of relationships with others, from basic functions such as the detection of emotions to more complex ones such as the understanding of irony (Adolphs, 2001; Couture et al., 2006; Green et al., 2008)), are still underexplored (Challet-Bouju et al., 2017; Hurel et al., 2019). To our knowledge, only one study has explored social cognition in those with GbD and suggested specific alterations in nonverbal emotional processing (Kornreich et al., 2016). Overall, despite the growing literature exploring neurocognition in those with GbD, further research is still needed (Balodis, 2020).

Regarding GmD, the analysis of the literature has also shown deficits in several tasks (go-nogo, Stroop, and SST) assessing inhibitory control (Argyriou et al., 2017). More specifically, GmD patients seem to display the same pattern of performance on an SST task as patients with an alcohol use disorder (Choi et al., 2014).

Regarding decision-making abilities, GmD patients also seem to choose riskier options (Billieux et al., 2020; Dong & Potenza, 2016; Schiebener & Brand, 2017) and have a preference for immediate rewards rather than later rewards (Billieux et al., 2020). Nevertheless, studies assessing decision making under uncertainty have obtained mixed results, and more research is needed (Billieux et al., 2020). Attentional bias towards videogame-related stimuli has also been highlighted in a group of players with an addiction to massively multi-player online role-playing games (MMORPGs) compared to non-addicted players and non-players (Metcalf & Pammer, 2011). Regarding social cognition, only three studies have been conducted in GmD to our knowledge, and these studies suggested deficits in specific pre-attentional emotional face processing (He et al., 2019; Peng et al., 2017) as well as specific patterns in social decision making (Su et al., 2018). Therefore, individuals with GmD seem to display patterns of neurocognitive functioning quite similar to those observed in individuals with GbD. Nevertheless, further research is needed to confirm these similarities and to characterize potential specific alterations.

Regarding FA, the research on neurocognition is less developed and inconsistent. One study showed, for example, that obese women with FA displayed worse performance than obese women without FA when assessing decision making in a situation of uncertainty and sustained attention (Steward et al., 2018). Nevertheless, these findings were not replicated when comparing patients with binge eating disorder and FA or patients with only FA to control patients with obesity and no FA (Blume et al., 2019), showing that further research is needed to characterize the neurocognitive functioning of patients with FA. Additionally, executive functioning was linked to (i) weight loss in groups of patients with obesity (Brockmeyer et al.,

2016; Wyckoff et al., 2017) and (ii) the presence of binge eating disorder (Córdova et al., 2017), showing the importance of cognition in the treatment of patients presenting with eating disorders, among whom there is a high prevalence of FA (Cassin & von Ranson, 2007).

Finally, a review of studies examining cognition in patients with SA was recently published (Grubbs et al., 2020). For example, one study found that these patients displayed enhanced attentional bias towards explicit cues in a visual dot-probe task (Mechelmans et al., 2014). Moreover, one study conducted with patients with compulsive sexual behavior showed a deficit in inhibitory control when they were compared to controls in a go-nogo task (Miner et al., 2009), while the examination of executive functioning of hypersexual men compared to controls showed no deficits (Reid et al., 2011). Finally, it was found in a group of users of internet pornography that participants with the lowest inhibitory control abilities in self-report and behavioral tasks displayed a higher score on a scale assessing addiction severity (Antons & Brand, 2018). Additionally, the tendency for cybersex addiction has been linked to executive function difficulties in a multitasking task in a non-clinical sample (Schiebener et al., 2015). These studies suggested the presence of neurocognitive alterations in SA samples, but further and more extensive research is still needed. In summary, the study of the neurocognitive profile of patients seeking treatment for BAs is still in its infancy, especially for certain disorders and cognitive functions.

Objectives of the BANCO and BANCO2 Protocols

Research on GbD, GmD, FA and SA has provided several clinical arguments suggesting that these disorders be brought closer to the concept of addictions. However, the neurocognitive characteristics associated with these disorders are still understudied, especially for SA and FA and for less investigated aspects of

neurocognition (social cognition or flexibility, for example). This literature gap may explain why the connections of BAs to the general concept of addiction is still the subject of debate and why certain disorders, clinically close to addictions, are not currently recognized as such. Indeed, to our knowledge, no research has been conducted involving several BAs, exploring a large panel of cognitive functions, and linking observations to clinical profiles. This type of research would permit (i) an exploration of potential common neurocognitive patterns among GbD, GmD, FA and SA in a transversal neurocognitive investigation of the concept of BA and (ii) an exploration of the specificities of each of them. Moreover, the exploration of BAs has the advantage of allowing the investigation of the neurocognitive characteristics of addictions without the neurotoxic effects linked to the ingestion of substances. Increasing knowledge in this field would thus provide a better understanding of addiction in general.

Thus, the main objective of the BANCO and BANCO2 studies is to investigate the neurocognitive profiles of patients with BAs and to compare them with matched healthy controls (HCs). The BANCO study involves GbD patients and their matched controls, while the BANCO2 study involves GmD, SA and FA patients and their matched controls. A secondary objective of these protocols is to compare each addiction with each other (including those investigated in separate studies) to (i) explore potential common neurocognitive patterns across BAs and (ii) identify specific characteristics linked to each BA. The global objective is to enhance the understanding of the general phenomenon of addiction by obtaining a precise profile of each addiction.

Finally, the last objective is to link neurocognitive observations to clinical profiles.

Trial Design

The two studies share the same methodology with a cross-sectional case-control design allowing comparison of several groups of patients with BAs with matched control groups (ie, participants without any history of a BA) on several neurocognitive tasks.

3.3.4. Method and Analysis

This study protocol was registered on ClinicalTrials.gov with the identification NCT03202290 for the BANCO study and NCT03967418 for the BANCO2 protocol. The studies began in August 2018 (BANCO protocol) and October 2019 (BANCO2 protocol). Recruitment is still in progress, and no analyses of the data have begun.

Participants

Patient and Public Involvement Statement

The patients and the public were not involved in the design, conduct, reporting, or dissemination plans of our research.

Sample Size Calculation

Given the exploratory aspect of this study and given the lack of data in the literature, sample size can be determined based only on recruiting capacities. Moreover, the sample sizes in case-control studies on GmD are usually quite small. For example, a recent meta-analysis exploring the inhibitory control abilities of participants with GmD (Argyriou et al., 2017) reported the results of studies assessing only 11 participants in one study and more than 30 participants in another (mean = 21 participants with GmD per study). Thus, this study is in the upper part of the range regarding the number of participants usually assessed.

Description of the Population

The participants included both patients with BAs and HCs. Patients were recruited from the Addictology Department of the University Hospital of Nantes. The

patient groups will include 120 participants seeking treatment for a BA; more explicitly, GbD (n=30), GmD (n=30), SA (n=30) and FA (n=30). Each group is matched on sex, age, and level of education with a group of 30 HCs. The 120 HCs are being recruited through media announcements (newspapers and radio), the Internet (link on the research team's website, institutional websites, professional networking), and the registry of volunteers for research that was constituted by the research team.

Eligibility Criteria

For all participants, the inclusion criteria are (i) being affiliated with the French healthcare system, (ii) being fluent in French (writing and reading), (iii) having appropriate levels of vision and hearing (with or without correction), and (iv) willing to accept the application of non-invasive electrodes. The non-inclusion criteria are (i) being under 15 years (for the FA, SA and GmD groups) and 18 for the GbD group as it is not legal to gamble before 18 years of age; (ii) presenting with current and non-stabilized cardiac, psychiatric, endocrine disorders or a lifetime psychotic disorder; (iii) presenting with a history of neurological disorders; (iv) receiving psychotropic treatment that had not been stabilized for at least two weeks; (v) presenting with colour blindness; underwent therapy focused on cognitive remediation; being under guardianship; (viii) presenting with a cognitive disorder that impacts daily functioning and could impact completion of the cognitive tasks described below; (ix) having participated in a clinical trial on a drug during the past month; (x) being pregnant; (xi) having electrical implants; (xii) having worked or studied in the field of psychology; and (xiii) having consumed psychoactive substances during the past 12 hours. To be included in one of the four patient groups, participants had to meet the diagnostic criteria of one of the BAs under study and to be at the beginning of their treatment (within six

months after the first appointment with the clinician). Regarding the FA group, eating disorders are accepted as current psychiatric comorbid disorders because they are a core feature of FA. The restrictive type of anorexia nervosa is not allowed because the concept of FA is not particularly valid in this disorder (Hebebrand et al., 2014). Table 20 presents measures used for the diagnosis of the BAs (patient groups).

Procedure

The first visit includes the collection of sociodemographic and clinical characteristics. The second visit includes the neurocognitive assessment. HCs complete both the clinical and neurocognitive assessments during the same visit (see Table 21 for a schedule). For patients, sociodemographic and clinical data are retrieved from the EVALADD cohort (NCT01248767). The criteria for discontinuing or modifying the assessment (clinical or neuropsychological) is the withdrawal of consent, which leads to the cessation of the assessment, or the

interruption of the assessment because of the health state of the participant (dizziness, anxiety, excessive fatigue, etc.), which could be followed by resumption of the assessment.

Clinical Assessment

The first visit included a standardized assessment of psychopathological characteristics, personality profile, and addiction-related characteristics (only for the patients) through self-reported questionnaires and clinical inter-views. Table 22 presents the content of the clinical assessment. Moreover, the experimenters also collect data regarding the following:

- sociodemographic characteristics (sex, age, education level, professional status);
- current treatments; and
- history of addiction (age of onset, duration, and several characteristics) - only for the patients.

Tableau 20 Measures used for the Diagnosis of BA - Manuscrit 5

Pathology	Diagnosis Criteria	Measures	Threshold
Gambling Disorder (GbD)	Gambling disorder section of the DSM-5	NODS (Gerstein et al., 1999) (fair internal reliability (Hodgins, 2004)) adapted to the DSM-5 criteria	Score ≥ 4
Sexual Addiction (SA)	Diagnostic criteria proposed by Carnes, Hopkins, and Green (2014) (P. J. Carnes et al., 2014)	In the absence of a validated diagnostic interview, the structure of the NODS is used, after adoption of Carnes' diagnosis criteria	Score ≥ 3
Gaming Disorder (GmD)	Internet gaming disorder section of the DSM-5 and gaming disorder section of the ICD-11	In the absence of a validated diagnostic interview, the structure of the NODS is used, after adaptation to the DSM-5 criteria for internet gaming disorder. Moreover, the experimenter systematically questions patients to ensure that they meet the definition of gaming disorder, as proposed in the ICD-11	Score ≥ 5
Food Addiction (FA)	Substances dependence criteria of the DSM-5	YFAS 2.0 (French validation, good internal consistency (Brunault et al., 2017))	Score ≥ 2 AND significant distress

DSM: Diagnostic and Statistical Manual of Mental Disorders; NODS: National Opinion Research Center DSM Screen for Gambling Problems; ICD: International Classification of Disease; YFAS: Yale Food Addiction Scale

Tableau 21 Schedule of Enrolments and Assessments Following SPIRIT Guidelines (Chan, Tetzlaff, Altman, et al., 2013; Chan, Tetzlaff, Gøtzsche, et al., 2013) - Manuscrit 5

	Study Period		
	Patient Groups		Control Group
	Enrolment	Assessment	Enrolment and Assessment
TIMEPOINT	-t ₁ *	t ₀ **	t ₀ **
ENROLMENT			
Eligibility screen	X		X
Informed consent	X		X
ASSESSMENTS			
Clinical Assessment	X		X
Neurocognitive assessment		X	X

Notes: *Less than six months before t₀; **Time zero, the day of the neurocognitive assessment, X: indicates the time point of each step of the study.

Neurocognitive Assessment

All participants (patients and HCs) performed the same assessment of neurocognitive functioning, including several cognitive tasks assessing a wide range of neurocognitive processes.

For several tasks, we use neutral, positive, negative, and addiction-related pictures (visual probe detection task, go-nogo task, stop-signal task, and cue-reactivity task) or words (Stroop task) (see [Supporting Files S1 \(Additional Tables 1 and 2\)](#) for the image and word selection procedure, *and in the Annex part of the manuscript*). The use of emotional and addiction-related stimuli allows us to differentiate a bias towards addiction-related stimuli or to general emotional stimuli (Hudson et al., 2016). Regarding the tasks using addiction-related pictures, we take into account the patient’s preference using a personalized research perspective. Each addiction has a list of several modalities of pictures (see details in Table 23), and the participant has to choose two modalities (except

for those with FA, who choose only one modality) that reflect his/her preferences.

Several cognitive tasks (visual probe detection task, go-nogo task, stop-signal task, Stroop task, delay discounting task, Iowa gambling task, and cue-reactivity task) are computerized (see [Supporting File S2](#) for details of the software and apparatus used *and at the end of the manuscript, in the Annex part*).

Cognitive Tasks

All the cognitive tasks used in the BANCO and BANCO2 studies are briefly described in this section, and more details are provided in [Supporting File S3 \(Additional Figure 1\)](#) *and in the Annex part of the manuscript*. The tasks are presented here in their order of presentation to the participants. For all of the tasks (except the cue-reactivity task), we include a concurrent assessment of metacognitive abilities (i.e., the ability to appraise, monitor, and control our thoughts (Martinez, 2006; Spada et al., 2015)).

Tableau 22 Measures Used for the Clinical Assessment – Manuscrit 5

	Measures Used	Clinical Data Obtained
Psychopathological characteristics	HAD (Hospital Anxiety and Depression Scale) (Zigmond & Snaith, 1983) (self-reported questionnaire, good reliability and discriminant validity) (Roberge et al., 2013)	Presence and severity of depression and anxiety symptoms
	MINI (Mini International Neuropsychiatric Interview, good sensitivity and specificity) (Lecrubier et al., 1997)	Screening of psychiatric and addictive disorders
	MIDI (Minnesota Impulsive Disorder Interview, good discriminant validity) (Chamberlain & Grant, 2018)	Screening of comorbid BAs
	WURCS-C (Wender Utah Rating Scale–short version) (Ward et al., 1993) (self-reported questionnaire, adequate internal consistency) (Romo et al., 2010)	Retrospective screening of ADHD during childhood
	ASRS (Adult ADHD Self-Report Scale Symptom Checklist) (Kessler et al., 2005) (self-reported questionnaire with a good sensitivity in a substance use disorder population) (van de Glind et al., 2013)	Presence of ADHD symptoms in adulthood
Addiction-related characteristics (only for participants for who the associated section of the MIDI is positive)	CPGI (Canadian Problem Gambling Index) (Ferris & Wynne, 2001) (self-reported questionnaire with adequate reliability)	Severity of gambling disorder
	PIUQ-JV (Problematic Internet Use Questionnaire) (Demetrovics et al., 2008), adapted for videogames (self-reported questionnaire with adequate psychometric proprieties calculated across nine European countries) (Laconi et al., 2019)	Severity of excessive use of videogames
	SAST-R (Sexual Addiction Screening Test-Revised) (P. Carnes et al., 2010) (self-reported questionnaire with an excellent internal consistency) (Hegbe et al., 2020)	Severity of sexual addiction
	EDI-2 (Eating Disorders Inventory-2) (Garner, 1991) (self-reported questionnaire with acceptable internal consistency in a binge eating disorder population) (Tasca et al., 2003)	Severity of eating disorders on multiple aspects
Personality	UPPS-P (Impulsive Behavior Scale) (Whiteside & Lynam, 2001) (self-reported questionnaire with a good internal reliability) (Van der Linden et al., 2006)	Impulsivity profile
	RSES (Rosenberg Self-Esteem Scale) (Rosenberg, 2015) (self-reported questionnaire with acceptable validity and fidelity) (Vallieres & Vallerand, 1990)	level of self-esteem
	TCI-125 (Temperament and Character Inventory) (Cloninger et al., 1993) (self-reported questionnaire with a good internal consistency) (Chakroun-Vinciguerra et al., 2005)	Temperament and character profile
	TAS-20 (Toronto Alexithymia Scale) (Loas et al., 1995) (self-reported questionnaire) (Loas et al., 1996, 1997)	Alexithymia profile

Tableau 23 Modalities Proposed for Addiction-Related Pictures - Manuscrit 5

Addiction	Proposed Modalities for Addiction-Related Pictures
GbD	Poker, casino, lotteries, sports betting, horse betting
GmD	MMORPG (massively-multiplayer online role-playing game), FPS (first person shooter), MOBA (multiplayer online battle area), and Sandbox and RTS (real-time strategy) together
SA	A woman alone, women, a man alone, men, man and woman together
FA	Sweet food, salted food or both sweet and salted food

Abbreviations: GbD, gambling disorder; GmD, gaming disorder; SA, sexual addiction; FA, food addiction.

Indeed, we ask the participant to self-rate his/her capacity to correctly perform a specific task before and after completing each task, which provides concurrent access to both appraisal and monitoring assessments. This form of metacognition assessment does not increase cognitive load because monitoring is not carried out during the task (Quiles et al., 2014). Moreover, to capture this measure, we use a modified version of the Positive/ Negative Behavioral Addiction Metacognition Scale (PBAMS/NBAMS) (Spada & Wells, 2008), which is a self-report questionnaire that assesses participants' general knowledge of their metacognitive capacities.

d2

The first cognitive task is the d^2 task, which is a standardized and normalized test assessing sustained attention. The participant is instructed to find a target (a "d" with two points) among distractors ("p" or a "d" with 1 or more than 2 points) (Brickenkamp, 2007).

Difference scores permit an evaluation of visual sustained attention capacities independent of processing speed abilities.

Stroop Task

This modified version of the Stroop task is used to assess cognitive inhibitory control related to addiction, as done in several studies (Boyer & Dickerson, 2003; Hester et al., 2006; Metcalf & Pammer, 2011; Pilli et

al., 2013). As in the original task, the first three parts include (i) the denomination of colours, (ii) the reading of words designating colours, and (iii) the designation of the colour of the ink in which words are written (Penner et al., 2012; Stroop, 1935). In the added emotional part of this modified version, the participant has to designate the colour of the ink in which negative, positive, neutral, and addiction-related words are written. This emotional part assesses the automatic treatment of emotional words and the presence of an interference bias towards words related to addiction (Dresler et al., 2009; Robbins & Ehrman, 2005).

Cue Reactivity

Cue reactivity (i.e., arousal and valence processing of stimuli) is measured by both subjective and objective measures (Trotzke et al., 2014). All pictures (neutral, positive, negative, and addiction-related) used for the other tasks (visual dot-probe, stop-signal, and go-nogo tasks) are presented one by one in the cue-reactivity task (which is the first computerized task that includes pictures). The participants simply look at the pictures, while several physiological indices are recorded to assess the objective emotional activation produced by pictures. The physiological indices are the inter-beat interval, skin conductance responses, and electromyography (EMG) of the corrugator supercilium and the zygomaticus major. Inter-beat interval and skin conductance measures provide information about the

autonomic nervous system responses to stimuli and about whether the patients respond to addiction-related pictures differently than emotional or neutral pictures and control participants. The two EMG electrodes permit us to distinguish a negative from a positive facial reaction (Tan et al., 2011). Afterward, participants subjectively rated the emotional valence and arousal of each picture, as well as the level of connection with the object of addiction (sex, gambling, food, or videogame). Each subjective assessment is performed on a scale ranging from 1 to 5. In addition to providing a subjective and objective rating of our material, this task allows us to ensure that the pictures are perceived as anticipated.

Visual Probe Detection Task (VDP)

This task explores selective attention. A pair of pictures (one is neutral, and the other one is the cue of interest, which could be neutral, positive, negative, or addiction-related) is presented on the screen to the left and right of a fixation cross (van Rooijen et al., 2017). The pictures are then replaced by a target that appears either to the right or the left of the fixation cross, and the participant has to detect the target as quickly as possible. Compared to the d^2 task, the visual probe detection task allows the identification of bias of engagement (congruent condition, with the target appearing at the same position as the cue of interest) and disengagement (incongruent condition, with the target appearing at the opposite position of the cue of interest) of attention towards emotional and addiction-related stimuli.

Iowa Gambling Task (IGT)

This task is used to evaluate decision making under uncertain conditions and was initially developed to assess patients with ventromedial prefrontal cortex lesions (Bechara, 2005; Damasio, 1994). This task is a computerized ecological task, and level of performance has been associated with the reward system and

inhibitory control abilities (Franken et al., 2008; Kovács et al., 2017). The participants are instructed to choose between 4 possible decks of cards (A, B, C, and D) (Bechara et al., 1994; Goudriaan et al., 2005). Each decision triggers a monetary gain but sometimes also a penalty that leads to a net loss. The level of gain and penalties vary between decks, which results in two advantageous decks and two disadvantageous decks. Behavioral and physiological responses associated with decisions are measured.

Verbal Fluency Tasks

This task assesses spontaneous flexibility, i.e., the flow of available ideas and the ability to generate many answers to one question by switching from category to category. The participants provide as many words beginning with the letter P as possible in two minutes (phonological modality) without saying the same word twice, without saying two words from the same family, and without saying a proper noun (Cardebat et al., 1990). The participants do this task a second time, but they have to provide as many words as possible that belong to a particular category (here, animals; lexical modality).

Trail Making Test (TMT)

This task (Lezak et al., 2004) evaluates reactive flexibility, which is the ability to switch from one set of operating rules to others and to adapt ways of thinking and acting depending on the context (Eslinger & Grattan, 1993). This task is a paper-and-pencil task in which participants must link encircled numbers (from 1 to 25) in increasing order (TMT-A). In the second part (TMT-B), the participants need to switch between two operating rules by alternately connecting numbers from 1 to 13 and letters from A to L. In the two parts, the participants must not lift their pen from the paper and must complete the task as fast as possible (Bowie & Harvey, 2006).

Modified Wisconsin Card Sorting Test (M-WCST)

This task (H. E. Nelson, 1976) also assesses reactive flexibility and rule deduction. The participants are given a deck of 48 cards that they have to match with 4 stimulus cards placed in front of them on the table. No information is given to the participant about how to match the cards, but the experimenter gives feedback on whether the match is right or wrong so that the participant can deduce the correct rule. Rules change during the task, and the experimenter informs the participant when this occurs so that the participant has to switch the type of matching to find the new rule.

French Version of the National Adult Reading Test (fNART)

The fNART measures premorbid intellectual efficiency (Mackinnon & Mulligan, 2005). It comprises a list of complicated words that do not follow usual pronunciation rules, and the participants have to read the list aloud. A good correlation between the English version of the NART and Wechsler Adult Intelligence Scale (WAIS-IV) performances, specifically the general ability index and the verbal comprehension index, has been shown in the healthy population (Bright et al., 2016). This measure permits us to control for the premorbid intelligence level of all participants and to take this variable into account as a confounding factor.

Complex Rey-Osterrieth Figure

This paper-and-pencil task involves a rectangle that surrounds and is surrounded by geometrical forms (Rey, 1941). The patients are instructed to copy it, which permits us to observe visuoconstruction abilities. Moreover, the way the participant builds his drawing (begins with the central rectangle, draws it element by element or even stroke by stroke) is an indicator of organizational strategies (J. E. Meyer & Meyer, 1996; Rey, 1959) and thus planning abilities. The experimenter records the order in which participants draw the elements, the score of the copy and time taken

to realize the drawing. The technique of switching colours of the pens every 30 seconds is not used, as this technique stops participants during their drawing and distracts them; therefore, a precise measure of time taken to draw is obtained (J. E. Meyer & Meyer, 1996).

Hanoi Tower

Regarding cognitive planning abilities, i.e., the capacity to anticipate and think ahead about the best way to properly perform a task, the Hanoi test is used to assess nonverbal planning abilities handled by the frontal lobe (Bishop et al., 2001) by means of a board with three tubes and five discs of different sizes. The participants have to put their board into the same arrangement as shown in the model (final position disposition). They must use the minimum number of moves possible, cannot move two discs at the same time, and cannot put a larger disc on a smaller one.

Squares (Subtest of the WAIS-IV Scale)

This task assesses visuospatial processing (Terriot & Mezza, 2014). In this task, the participant is given 4 to 9 identical cubes (each of them with two white sides, two red sides, and two bicolour sides). Then, the experimenter shows the participant several paper sheets (up to 14), each with the model to be reproduced by the participant, including a specific pattern on the top of the cubes. The experimenter records scores with and without time bonuses to observe the impact of speed processing on participant performance.

Go-Nogo Task

This task permits the assessment of the ability to stop an automatic response induced by stimuli (motor inhibition) (Miyake et al., 2000). The participants are asked to press a button as fast as possible when the go signal is presented and to not press the button when the nogo signal appears. The go signals are much more numerous than nogo signals to maintain the urge to respond. We use an emotional version of the task

(Brown et al., 2015; Schulz et al., 2007; van Holst et al., 2012), in which go and nogo signals include a background with neutral, positive, negative, or addiction-related pictures.

Single Key Impulsivity Paradigm (SKIP)

This task assesses the tolerance for delayed rewards. The SKIP task is a “free operant procedure” (Dougherty et al., 2008), which means that the procedure does not include multiple trials with discrete possible answers. Over the 10 minutes, the participants can press a button whenever they want to obtain points, which are given in proportion to the delay between consecutive responses (the longer the delay is, the greater the number of points).

Mini Social and Cognition and Emotional Assessment (Mini-SEA)

The mini-SEA (Bertoux et al., 2012) includes two subtests: the “faux pas” task and an emotion recognition task.

“Faux Pas” Task

The participants read 10 stories in which they have to detect if one of the characters made a social mistake by accident. Five of the 10 stories are distractors, meaning that there is no social mistake in it. For each story, the experimenter asks control questions to ensure that the participant has well understood the situation and other questions to assess the detection of the mistake.

Emotion Recognition

This task consists of the presentation of 35 pictures of faces in black and white on a paper sheet. The participants have to choose which emotions are displayed by the faces from among seven possible answers (surprise, happiness, fear, anger, sadness, neutral, disgust). Reaction times are not collected, but the participants are instructed to spontaneously answer with a 12-second maximum.

Stop-Signal Task (SST)

This task assesses the ability to interrupt an already initiated motor response in a context where automatic inhibition is unlikely to occur. The participants are asked to categorize a target (arrow directed to the left or the right), but in a quarter of the trials, an audio stop signal occurs with a variable delay, and the participant has to refrain from responding. We use an emotional version (Lorains et al., 2014) in which the target includes a background with neutral, positive, negative, or addiction-related pictures.

Data Management

All included participants are given an identification number, depending on the group of inclusion. The link between numbers and the identity of the patients is accessible only to authorized members and is kept separate from the research data. This data will be available only to units involved in this project (Addictology Department of the CHU of Nantes and the biometry platform from the University Hospital of Nantes). The data from the computerized tasks are processed with Excel and R programs. The data from neuropsychological tasks that are not computerized are collected on the case report form. All collected data are then entered and coded with EpiData software (EpiData Association, <http://www.epidata.dk>). This software is hosted on a hospital server and is therefore accessible only to authorized members.

Statistical Analysis

To compare the global level of cognitive functioning of that patients with that of the HCs, a composite score will be created based on all the cognitive measures. It will be computed based on a principal component analysis performed on all the cognitive measures by retaining only the principal dimension as a latent variable. For each group of patients, linear models will be used to compare the composite scores of individuals with BAs to their matched HCs, including

a random effect on matched patient/HC pairs. Moreover, to identify which specific cognitive functions are altered in individuals with BAs, each cognitive measure will be independently compared between the patients and their matched HCs. Logistic models (for qualitative outcomes) and/or linear models (for quantitative outcomes), including a random effect on matched patient/HC pairs, will be performed.

To identify specific alterations linked to each BA and to explore common deficits across different BAs, the composite scores and each cognitive measure will be compared between each pair of patient groups. Linear models explaining the composite score and the neurocognitive scores by the BA group will be performed.

Finally, a multidimensional descriptive analysis (principal component analysis) will be performed to investigate the links between clinical data and cognitive test performance.

All the analyses will control for possible confounding factors that may affect performance in the different cognitive tasks (for example, the premorbid intelligence level, the history of attention-deficit/hyperactivity disorder or past substance-use disorders). In the case of a significant difference between the two groups, confounding factors will be entered as covariates in the statistical analyses.

In the case of premature cessation of the assessment or missing data, the missing data will be imputed with a “worst case” scenario (i.e., by replacing the missing data with the worst value obtained in that participant’s group). For variables in which 10 to 20% of data are missing, a sensitivity analysis will be performed by testing other scenarios (imputation by the mean, multiple imputation, etc.). If more than 20% of the data are missing, the data will not be imputed.

Monitoring

No data monitoring committee is needed because this research involves only benign risks for the participants. No unintended effects of the trial are expected.

3.3.5. Discussion

Expected Results and Clinical Implications

This study has several perspectives, both from scientific and clinical points of view.

From a scientific point of view, the results may provide new knowledge regarding the cognitive functioning of patients with BAs and open several areas of research. First, the results will provide new information regarding common patterns between different BAs and will contribute to the debate regarding the inclusion of BAs in the addictive spectrum. More specifically, this research programme will contribute to extending the literature regarding underexplored BAs, such as SA and FA. Indeed, in 2013, GmD was considered in need of further research before inclusion in the “Substances-related and addictive disorders” in the DSM-5 and recognition as a BA in the ICD-11, while GbD was recognized in 2013 in the DSM-5 and in 2018 in the ICD-11. This gradual inclusion in international classification systems shows that BAs are becoming increasingly recognized. FA and SA need further research to improve their assessment and clarify their characteristics (American Psychiatry Association, 2013; Petry et al., 2018) before considering their possible inclusion as addictive disorders in these international classification systems. Second, the exploration of BAs represents an interesting model for increasing knowledge on the cognitive alterations involved in addictive disorders in general. Indeed, as BAs do not involve the consumption of psychoactive substances, this research programme will also provide a better understanding of the cognitive processes that underlie substance-related addictive disorders (Karim &

Chaudhri, 2012). This is because the ingestion of psychoactive substances alters neurocognitive functioning and may influence the evaluation of cognitive mechanisms underlying addiction in those with substance use disorders (Albein-Urios et al., 2012). Finally, this study explores cognitive functions that are still underexplored, such as social cognition and metacognition (Challet-Bouju et al., 2017; Hurel et al., 2019) and will provide new results examining functions that have produced mixed results, such as flexibility or decision making (Rochat et al., 2019). This will permit a better understanding of common and specific neurocognitive patterns in several BAs and improve the understanding of the factors that trigger and maintain BAs and addictions in general.

From a clinical perspective, several applications may be considered. First, the inclusion of these BAs in the addictive spectrum would permit the development of pan-addiction treatments for both substance-related and other addictive disorders. Knowledge about the clinical management of substance use disorders could benefit patients presenting with BAs (Di Nicola et al., 2015; Marazziti et al., 2014; Olsen, 2011). For example, molecules already tested for substance use disorders may also be used for BAs. This is the case for opioid antagonists such as naltrexone, which was tested in patients with compulsive sexual behavior (Leppink & Grant, 2016) or GbD (Aboujaoude & Salame, 2016; Mouaffak et al., 2017), or nalmefene, which was tested in patients with GbD (Kraus et al., 2020). Moreover, a transversal approach would permit clinicians to not surcharge for multiple therapies and improve the impact of therapies because of co-occurrences (H. S. Kim & Hodgins, 2018). Indeed, when comparing patients with both an alcohol use disorder and a BA to patients with only an alcohol use disorder, it seems that the presence of the BA is linked with increased craving and impulsivity (Di Nicola et al., 2015). Co-occurrences of

substance use disorder and BAs thus seem to impact treatment. Treating both addictions as a unique entity would permit us to focus therapy on common underlying processes using, for example, motivational interviewing or cognitive therapy, rather than trying to treat two distinct mental disorders. Second, increasing knowledge about specific cognitive alterations could permit the development of new therapies focused on such deficits. In fact, in the field of addiction, cognitive remediation therapy has mainly been developed for substance use disorder, in which it showed the reversibility of cognitive alterations linked to the ingestion of psychoactive substances through top-down (Bell et al., 2016; Rass et al., 2015) and bottom-up (Gladwin et al., 2016) therapies. Nevertheless, the impact of these therapies on addictive behaviors requires further research (Manning et al., 2017). Regarding BAs, there are ongoing cognitive remediation programmes for individuals with GbD, even if no formal efficacy has been demonstrated (Challet-Bouju et al., 2017; Luquiens et al., 2019). Moreover, a programme of cognitive bias modification showed preliminary positive findings regarding the diminution of urges and cue reactivity for those with GmD (Rabinovitz & Nagar, 2015). However, despite growing evidence regarding the importance of cognitive functioning in BAs, further research is needed to better characterize the cognitive profiles to build specific cognitive remediation programmes. Finally, it has been shown that cognitive functioning, and more specifically impulsive decision making, impacts the efficacy of treatment in individuals with substance use disorders (Manning et al., 2017; Stevens et al., 2014). Moreover, research has shown in a group of GmD patients that the amelioration of clinical symptoms seems to be accompanied by improvements in neurocognitive functioning after six months of outpatient treatment (Lim et al., 2016). Thus, these studies show the importance of taking cognitive functioning into account

when trying to understand and treat addictive mechanisms.⁴⁵

3.3.6. Limits

There are several eligibility criteria that do not permit the inclusion of all patients in our service. Therefore, this study will last at least two years, but it will permit us to reduce bias linked to confounding factors such as psychiatric comorbidities and to observe the neuropsychological profile linked to a particular BA. Moreover, this study is exploratory and will need to be replicated by others to confirm the results. Finally, this study adopts a cross-sectional design, while a longitudinal design would have provided more information. Indeed, this latter type of study would have permitted an assessment of changes in assess cognitive functioning in connection with relapses or abstinence or the impact of the level of cognitive functioning on treatment. Nevertheless, characterizing the cognitive profile at the beginning of treatment may permit the assessment of outstanding features specific to BAs that can be assessed longitudinally in subsequent studies to assess the links between cognition and BAs throughout treatment, relapse or abstinence.

Dissemination Policy

The results of this study will be communicated to participants (collective results) and to the scientific community by means of oral communications, scientific articles, and a Ph.D. thesis. All research employees involved in the study may communicate about this research. Scientific articles may be edited by professionals for issues related to the English language.

Data Sharing Statement

The datasets generated and/or analysed during the current study will not be publicly available due the presence of private and medical data but will be available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This research programme is conducted following Good Clinical Practice Guidelines and the Declaration of Helsinki, with approval from the French national ethics committee (Comité de Protection des Personnes; CPP OUEST III for BANCO and SUD-EST VI for BANCO2).

All participants provided written informed consent collected by investigators. An amount of €75 is given to compensate for the travel costs incurred for the research visit.

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Author Contributions

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work.

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Disclosure

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Les références sont incluses dans l'annexe Références du document complet.

3.3.7. Résultats préliminaires de l'étude BANCO

Au moment de la rédaction de cette thèse, les inclusions dans l'étude BANCO étaient toujours en cours. Ainsi, cette partie permet de présenter les résultats préliminaires obtenus pour le groupe de patients JAP avec leur sujets contrôles appariés (n=11 patients et n=11 sujets contrôles). Les données concernant le JVP ne seront pas abordées puisque trop peu de patients ont été inclus (n=4 patients, n=2 contrôles).

Les groupes ont été comparés grâce à des tests de rangs exacts appariés de Wilcoxon car le nombre de sujets inclus était trop petit pour pouvoir utiliser des tests paramétriques.

3.3.7.1. Description de la population

A ce jour, nous avons pu appairer 11 contrôles à nos patients (uniquement des hommes) dont les caractéristiques sont présentées dans le Tableau 24. Les données associées à l'analyse du fNART sont dans la partie Annexe de la thèse. Aucune différence entre groupe n'a été montrée sur le nombre de mots correctement lus, et aucune corrélation n'apparaissait avec les scores sur les tâches de faux-pas, de reconnaissance des émotions ni les scores normalisés de métacognition sociale, suggérant que les capacités d'intelligence prémorbide n'ont pas impacté la performance sur les tâches de CS.

Tableau 24 Analyses descriptives des participants à l'étude BANCO

Variables	Groupe JAP	Groupe contrôle
Données sociodémographiques		
	Moyenne (écart- type) [minimum – maximum]	Moyenne (écart-type) [minimum – maximum]
Nombre de participants	11	11
Age	33.18 (10.42) [21 – 57]	33.00 (10.50) [20 – 57]
Nombre d'années d'études	13.82 (2.32) [9 – 17]	13.91 (1.81) [11 – 17]
Données de psychopathologie issues du MINI		
Diagnostic d'épisode dépressif majeur actuel	1	0
Diagnostic d'épisode dépressif majeur passé	4	1
Risque suicidaire	0	2
Manie passée	1	0
Trouble panique passé	1	0
Agoraphobie actuel	1	0
Phobie social actuelle	1	0
Etat de stress post traumatique actuel	1	0
Etat de stress post traumatique passé	0	1
Anxiété généralisée actuelle	1	0
Trouble de la personnalité antisociale	1	0

Trouble de l'usage de l'alcool actuel	3	1
Trouble de l'usage de l'alcool passé	0	3
Trouble de l'usage du tabac actuel	4	0
Trouble de l'usage du tabac passé	1	2
Trouble de l'usage des cannabinoïdes actuel	2	0
Trouble de l'usage des cannabinoïdes passé	0	1
Diagnostic de TDA/H	1	0
Données liées aux JHA		
Moyenne d'âge lors du premier jeu	15.73 (4.2)	14.64 (4.72)
	[7 – 21]	[6 -21]
Score au NODS	6.73 (1.74)	0.36 (0.67)
	[4 – 9]	[0 – 2]
Jeu de prédilection		
<i>Euromilion</i>	0	3
<i>Loto</i>	0	3
<i>Paris hippiques</i>	3	1
<i>Paris sportifs</i>	6	3
<i>Poker</i>	2	1
Fréquence de jeu		
<i>Plus d'une fois par semaine</i>	11	6
<i>1 fois par semaine</i>	0	1
<i>1 fois ou plus par mois</i>	0	3
<i>Moins d'une fois par mois</i>	0	1
<i>N'a pas joué dans la période actuelle</i>	0	0

Les diagnostics de dysthymie, d'hypomanie, de trouble obsessionnel compulsif, de troubles du comportement alimentaire actuel et de troubles de l'usage des substances (stimulants, opiacés, hypnotiques, hallucinogènes, substances inhalées) ne sont pas indiqués car aucun participant ne présentait ces diagnostics. JHA=jeux de hasard et d'argent ; MINI = Mini-International Neuropsychiatric Interview ; NODS= National Opinion Research Center DSM-IV Screen for Gambling Problems ;TDA/H = Trouble de l'attention avec ou sans hyperactivité.

3.3.7.2. Résultats aux tâches cognitives et aux questionnaires et comparaison de groupes

Les statistiques descriptives des tâches de la mini-SEA (Bertoux et al., 2012) ainsi que les p-values des comparaisons entre le groupe JAP et le groupe contrôle sont présentées dans le Tableau 25. Aucune différence n'apparaissait significative entre le groupe contrôle et le groupe JAP. Pour les auto-questionnaires, une différence significative a pu être mise en évidence entre les deux groupes sur les niveaux de dépression, d'anxiété, de difficulté à identifier ses émotions ainsi que le score d'addiction. Pour chacune de ces mesures, les patients JAP présentaient des niveaux plus élevés que les sujets contrôles.

Tableau 25 Statistiques descriptives et de comparaison de groupe de l'étude BANCO

	Groupe JAP	Groupe contrôle	
	Moyenne (écart-type) [Minimum – maximum]	Moyenne (écart-type) [Minimum – maximum]	p value de la comparaison de groupes
Tâches cognitives évaluant la CS			
Faux-pas			
Score histoires faux-pas (/30)	27.36 (2.87) [21 – 30]	25.36 (4.54) [16 – 30]	0.100
<i>Question d'identification faux-pas et non faux-pas (/15)</i>	14.64 (0.67) [13 – 15]	14.55 (0.69) [13 – 15]	1
<i>Question d'identification du personnage fautif (/5)</i>	4.82 (0.40) [4 – 5]	4.36 (0.81) [3 – 5]	0.063
<i>Question d'explication (/5)</i>	4.64 (0.67) [3 – 5]	4.36 (0.81) [3 – 5]	0.375
<i>Question de justification (/5)</i>	4.36 (0.81) [3 – 5]	4.27 (1.01) [2 – 5]	1
<i>Question d'intentionnalité (/5)</i>	4.64 (0.50) [4 – 5]	4.27 (0.90) [2 – 5]	0.250
<i>Question d'émotion ressentie (/5)</i>	4.09 (0.94) [2 – 5]	3.55 (0.93) [2 – 5]	0.172
Score histoires non faux-pas (/10)	9.82 (0.60) [8 – 10]	10.00 (0.00) [10 – 10]	1
Score total (/40)	37.18 (3.09) [31 – 40]	35.36 (4.54) [26 – 40]	0.152
Score questions contrôles (/20)	20.00 (0.00) [20 – 20]	19.73 (0.65) [18 – 20]	0.5
Reconnaissance des émotions faciales			
Total (/35)	29.27 (3.04) [25 – 34]	28.00 (3.26) [23 – 33]	0.379
<i>Joie (/5)</i>	4.91 (0.30) [4 – 5]	5.00 (0.00) [5 – 5]	1
<i>Peur (/5)</i>	3.64 (0.92) [2 – 5]	3.00 (1.48) [0 – 5]	0.283
<i>Dégoût (/5)</i>	4.45 (0.69) [3 – 5]	4.09 (1.22) [2 – 5]	0.578
<i>Colère (/5)</i>	3.55 (1.29) [1 – 5]	3.45 (0.93) [2 – 5]	1
<i>Surprise (/5)</i>	4.45 (0.69)	4.91 (0.30)	0.188

	[3 – 5]	[4 – 5]	
<i>Tristesse (/5)</i>	3.45 (1.21)	2.82 (1.66)	0.254
	[2 – 5]	[1 – 5]	
<i>Neutre (/5)</i>	4.82 (0.40)	4.73 (0.90)	1
	[4 – 5]	[2 – 5]	
Métacognition sociale (scores moyens non normalisés)			
<i>Avant la tâche de faux - pas</i>	75.00 (10.49)	73.18 (15.54)	
	[60 – 90]	[50 – 100]	
<i>Après la tâche de faux - pas</i>	83.64 (10.27)	80.45 (16.19)	
	[70 – 100]	[60 – 100]	
<i>Avant la tâche de reconnaissance des émotions faciales</i>	80.45 (10.11)	77.27 (10.81)	NA
	[60 – 90]	[60 – 100]	
<i>Après la tâche de reconnaissance des émotions faciales</i>	82.27 (9.58)	79.27 (12.44)	
	[70 – 95]	[60 – 100]	
Auto-questionnaires			
HAD totale	13.73 (5.48)	6.82 (4.42)	0.010
	[5 – 23]	[1 – 14]	
HAD – échelle anxiété	8.72 (3.41)	4.81 (2.64)	0.009
	[4 – 14]	[1 – 9]	
HAD – échelle dépression	5 (2.68)	4.82 (2.64)	0.008
	[1 – 9]	[1 – 9]	
TAS-20			
<i>Total</i>	50.56 (10.77)	41.73 (10.07)	0.098
	[32 – 64]	[30 – 62]	
<i>Difficulté à identifier ses émotions</i>	16.50 (5.32)	11.27 (4.24)	0.041
	[7 – 23]	[7 – 19]	
<i>Difficulté à décrire ses émotions</i>	13.89 (5.62)	11.27 (4.15)	0.258
	[5 – 21]	[6 – 19]	
<i>Pensées orientées vers l'extérieur</i>	19.60 (2.22)	19.18 (4.05)	0.791
	[17 – 23]	[13 – 27]	
Score au NODS	6.73 (1.74)	0.36 (0.67)	0.001
	[4 – 9]	[0 – 2]	

CS = cognition sociale, HAD = Hospital Anxiety and Depression, JAP=jeu d'argent pathologie; NA=Non applicable, NODS= National Opinion Research Center DSM-IV Screen for Gambling Problems ; TAS-20=Toronto Alexithymia Scale. Les p values en gras indiquent une valeur sous le seuil significatif de 0.05.

3.3.7.3. Analyses de corrélation

Les comparaisons de groupe sur les tâches cognitives n'ont pas permis de mettre en évidence de différence significative entre les patients présentant un diagnostic de JAP et le groupe contrôle. Des analyses complémentaires de corrélation ont été effectuées entre les scores aux tâches cognitives et les échelles pour lesquelles une différence significative entre les deux groupes ont été démontrées (score de sévérité de l'addiction, de niveau de dépression et d'anxiété et de difficulté à identifier ses émotions). Ces analyses permettaient d'observer le lien entre caractéristiques cliniques et performance de CS pour mieux comprendre les influences de chaque variable. Les coefficients de corrélation sont présentés dans le Tableau 26. Aucune corrélation n'apparaissait significative.

Tableau 26 Coefficients de corrélation entre les tâches cognitives et le score de sévérité de l'addiction

Variable corrélée avec le score du NODS	Score de sévérité de l'addiction	TAS – Difficulté à identifier ses sentiments	HAD - Anxiété	HAD - Dépression
Faux-pas				
Score histoires faux-pas	0.16	0.14	0.11	0.18
<i>Question d'identification faux-pas et non faux-pas</i>	0.07	0.31	0.19	0.21
<i>Question d'identification du personnage fautif</i>	0.20	0.29	0.37	0.39
<i>Question d'explication</i>	0.11	0.23	0.20	0.21
<i>Question de justification</i>	-0.11	0.11	0.01	0.028
<i>Question d'intentionnalité</i>	0.19	0.20	0.20	0.24
<i>Question d'émotion ressentie</i>	0.23	-0.07	0.03	0.05
Score histoires non faux-pas	-0.12	0	-0.35	-0.36
Score total	0.14	0.13	0.06	0.13
Score questions contrôles	0.20	0.36	0.27	0.22
Reconnaissance des émotions faciales				
Total	0.13	-0.08	0.07	0.09
<i>Joie</i>	-0.18	-0.09	-0.07	-0.02
<i>Peur</i>	0.06	-0.18	-0.03	-0.05
<i>Dégoût</i>	0.12	0.14	-0.05	0.02
<i>Colère</i>	0.05	-0.06	0.12	-0.04

<i>Surprise</i>	-0.37	-0.21	-0.13	0.01
<i>Tristesse</i>	0.19	0.09	0.30	0.18
<i>Neutre</i>	-0.10	-0.26	-0.22	0.01

3.3.7.4. Etude de la métacognition

Les scores de métacognition ont été normalisés (centrés sur la moyenne et l'écart-type) en utilisant la moyenne et l'écart-type de tous les scores en CS. Les scores de métacognition ont été comparés entre les groupes (voir Tableau 27).

Tableau 27 Comparaison entre les groupes et coefficients de corrélation avec le score de sévérité de l'addiction sur les scores normalisés de métacognition

			Coefficients de corrélation			
			Score de sévérité de l'addiction	TAS20 – DIS	HAD - Anxiété	HAD - Dépression
Métacognition faux-pas	avant	0.17	-0.40	-0.17	-0.14	-0.14
Métacognition faux-pas	après	0.28	-0.04	0.09	-0.03	0.01
Métacognition Reconnaissance émotions faciales	avant des	0.76	0.01	-0.21	-0.25	-0.20
Métacognition Reconnaissance émotions faciales	après des	0.74	0.22	0.15	0.17	0.14

DIS=Difficulté à identifier ses sentiments, HAD=Hospital Anxiety And Depression Scale ; TAS=Toronto Alexithymia Scale

Les analyses ne montraient pas de différence significative entre les groupes. Une étude de corrélation entre le score de sévérité de l'addiction a été effectuée pour observer le lien entre addiction et niveau de métacognition. Aucune corrélation n'apparaissait significative.

L'étude de la qualité de la métacognition était effectuée en calculant la corrélation entre le score aux tâches cognitives et le score de métacognition. En effet, une corrélation significative signifie qu'il y a un lien entre l'estimation réalisée et la performance à la tâche cognitive. Dans ces analyses préliminaires, aucune corrélation n'apparaissait significative (voir Tableau 28).

Tableau 28 Coefficients de corrélation entre les tâches cognitives et les scores de métacognition

	Métacognition avant	Métacognition après
Faux-pas		
Score histoires faux-pas	0.08	-0.10

<i>Question d'identification faux-pas et non faux-pas</i>	0.22	-0.14
<i>Question d'identification du personnage fautif</i>	0.25	0.08
<i>Question d'explication</i>	0.19	0.02
<i>Question de justification</i>	0.10	0.10
<i>Question d'intentionnalité</i>	-0.05	-0.06
<i>Question d'émotion ressentie</i>	0.14	-0.18
Score histoires non faux-pas	-0.28	-0.14
Score total	0.06	-0.13
Score questions contrôles	0.09	0.28
Reconnaissance des émotions faciales		
Total	-0.15	0.12
<i>Joie</i>	0.24	-0.28
<i>Peur</i>	-0.47	0.38
<i>Dégoût</i>	-0.03	-0.11
<i>Colère</i>	-0.15	0.07
<i>Surprise</i>	0	0.07
<i>Tristesse</i>	0.05	0.10
<i>Neutre</i>	0.52	-0.06

3.3.8. Discussion et perspectives des résultats préliminaires de l'étude BANCO

L'analyse préliminaire des tâches de CS de l'étude BANCO permet de démontrer d'ores et déjà une différence entre les groupes sur le plan de la dépression, de l'anxiété et de la difficulté à identifier ses émotions.

Sur les tâches cognitives présentées, évaluant notamment la capacité de reconnaissance des émotions faciales, ainsi que la capacité à reconnaître un faux-pas (TdE), aucune différence significative n'a été démontrée entre les groupes. Ces tâches n'ont pas permis non plus de montrer de lien significatif avec les mesures cliniques de l'addiction, de psychopathologie ou encore d'empathie rapportées par les patients.

L'absence de différence peut en premier lieu être imputée à la taille de l'échantillon. En effet, notre groupe de patients et notre groupe contrôle ne comprenaient que 11 participants chacun, alors que l'objectif d'inclusion est de 30 participants par groupe. En comparaison, l'étude de Kornreich et al. (2016) incluait 22 participants dans chaque groupe. Il sera ainsi nécessaire d'effectuer de nouveau les analyses pour confirmer l'absence de différence entre les groupes.

Concernant l'outil utilisé, la mini-SEA a permis de démontrer une altération des capacités de CS dans le trouble de l'usage de l'alcool (Cox et al., 2018). Une nouvelle fois, l'échantillon évalué était plus

important (40 contrôles et 45 patients). Dans cette étude, les patients avec un trouble de l'usage de l'alcool avaient des performances significativement plus faibles que les contrôles sur la tâche de faux-pas, ainsi que sur la capacité à reconnaître la peur, le dégoût, la colère et l'absence d'émotion (neutre). Par ailleurs, les niveaux d'anxiété et de dépression étaient négativement corrélés avec la capacité à identifier une émotion correctement pour le groupe de patients. Un lien significatif négatif entre le score de dépression et les sous-scores de faux-pas a aussi été démontré pour le groupe de patients. La pertinence de l'utilisation de cet outil est donc réelle et permettrait de confirmer ou d'infirmer la présence d'altération de la CS dans les ACs. En outre, si des altérations apparaissent finalement dans les analyses finales, il sera possible de conclure que cette altération n'est pas due à l'ingestion de substances psychoactives neurotoxiques que l'on retrouve dans les TUS, mais bien en lien avec les processus addictifs.

Enfin, si finalement les analyses finales de l'étude BANCO ne permettent pas de démontrer une altération de la CS, cela peut suggérer que certaines altérations de la CS peuvent être liées plutôt à l'ingestion de substances neurotoxiques qu'à l'addiction en elle-même. Il est aussi possible de mettre l'absence de résultats en lien avec les caractéristiques de la mini-SEA. En effet, et notamment pour les sous-score de faux-pas, les sujets contrôles présentent de manière générale une réussite quasi-systématique à tous les items (Quesque et al., 2020) ce qui suggère la présence d'un effet plafond (tâche trop facile pour discriminer des performances dans la norme ou au-dessus). Etant donné que le déficit recherché dans l'AC n'est pas massif, il est possible que cette limite de l'outil ne permette pas de conclure à l'absence d'altération de la TdE pour nos patients. Si les résultats finaux ne permettent pas de discriminer les patients JAP des contrôles, il sera possible d'utiliser une tâche plus complexe telle que la tâche de *Reading the Mind in the Eyes Test* (Baron-Cohen et al., 2015). Cette tâche a permis de démontrer une altération de la capacité à identifier une émotion sur des stimuli ne comprenant que les yeux dans le trouble de l'usage de l'alcool (Bora & Zorlu, 2016; Maurage, Grynberg, Noël, Joassin, Hanak, et al., 2011) et un lien avec le niveau de sévérité de JVP (Aydın et al., 2020; Yavuz et al., 2018).

Pour finir, malgré notre faible effectif, ces analyses préliminaires ont permis de démontrer que les patients ressentent des difficultés à identifier leurs émotions grâce à l'échelle de la TAS-20 (Loas et al., 1995). L'alexithymie est un facteur important dans le déclenchement du JAP (Gori et al., 2022). Or, le niveau d'alexithymie semble avoir un impact sur les capacités de CS et notamment pour reconnaître des émotions faciales (Grynberg et al., 2012). Proposer de la RC axée sur la CS prend ainsi tout son sens, même si nous ne parvenons pour le moment pas à mettre en évidence de déficit via l'utilisation de tâches neuropsychologiques. Ce travail de RC permettrait ainsi d'améliorer le fonctionnement social (Kurtz et al., 2016; Kurtz & Richardson, 2012) et la CS en elle-même (Lahera et al., 2013). Ainsi, ce type de thérapie est une piste importante à prendre en compte lors de la prise en charge de patients présentant un diagnostic de JAP.

Sur le plan clinique, ces analyses préliminaires rappellent l'importance d'évaluer les compétences sociales lors de la prise en charge de patients présentant une AC. Il est par exemple possible d'utiliser en premier lieu un questionnaire tel que la TAS-20 (Loas et al., 1995) qui permet d'évaluer de manière rapide le niveau d'alexithymie. Cela permet par la suite d'orienter si nécessaire vers une évaluation plus complète de la CS par un bilan neuropsychologique. Ces différentes évaluations permettront d'indiquer ou non la nécessité d'effectuer un travail de RC axé sur les capacités de CS.

PARTIE 4. DISCUSSION, LIMITES ET PERSPECTIVES

Cette dernière partie reprend les questions de recherche de ce travail de thèse, et résume les résultats obtenus concernant les capacités de CS dans les ACs. Les implications cliniques en lien avec ces résultats sont discutées et illustrées à l'aide d'un cas clinique. Enfin, les limites des études menées et les perspectives d'études possibles à venir sont présentées.

Article présenté dans cette partie :

- Manuscrit 6 publié dans *Journal of Behavioral Addictions* :

Hurel, E., Challet-Bouju, G., Chirio-Espitalier, M., Vincent, M., & Grall-Bronnec, M. (2021). Social communication disorder and behavioural addiction: Case report and clinical implications. *Journal of Behavioral Addictions*, 1(aop). <https://doi.org/10.1556/2006.2021.00026>

- ❖ Cas clinique présenté *via* une communication affichée lors du 14^{ème} congrès international d'Addictologie de l'Albatros, du 10 au 12 juin 2020, à Paris, sous le titre : « Cognition sociale et addiction comportementale ».

4.1. Discussion

4.1.1. Résultats issus de ce travail de thèse

Dans cette partie, et comme défini dans le manuscrit des études BANCO et BANCO2, le terme AC intègre le JVP, le JAP, mais aussi l'AS et l'AA. Pour rappel, ce travail de thèse avait pour but de questionner le lien entre CS et AC.

Comment cette question a-t-elle été étudiée dans la littérature ? Que sait-on du profil de CS dans les ACs ?

Ce travail de thèse a permis de démontrer, grâce à l'analyse systématique de la littérature, la rareté des études liant CS et AC. Concernant le JAP (manuscrit 1), une unique étude, comparant des patients à des sujets contrôles, a évalué la capacité à reconnaître des émotions sur des visages ou en écoutant des voix. Les résultats de cette recherche suggéraient une altération de ces compétences. Concernant le JVP (manuscrit 2), toutes les études répertoriées dans la littérature démontraient des particularités pour les groupes de patients présentant un diagnostic de JVP, et notamment un traitement spécifique des émotions faciales, un profil particulier sur le plan de la coopération ou encore des capacités de TdE.

Par ailleurs, une mise à jour de la revue concernant le JAP et la CS a été effectuée en mars 2022. A notre connaissance, aucune nouvelle recherche n'est parue depuis 2018. Certains articles font pourtant le lien entre alexithymie et développement de problématiques addictives (Gori et al., 2022). D'autres études ont montré une relation entre le déficit de mentalisation auto-rapporté et le fait d'avoir une pratique problématique des JHA chez des adolescents (Ciccarelli et al., 2021) et avec le comportement de *chasing* (Nigro et al., 2019).

Existe-t-il une altération des capacités de CS dans les ACs ?

Les études présentées à la suite de ces travaux cherchaient ainsi à alimenter la littérature liant CS et AC de manière à mieux appréhender le rôle de la CS dans les processus addictifs. L'étude PERHAPS (manuscrit 3) a permis de démontrer qu'en dehors de toute addiction, les joueurs de poker présentaient des spécificités dans leur allocation de l'attention avec des indices sociaux. En effet, ces sujets présentaient une durée d'IDR plus importante.

L'étude eSMILE (manuscrit 4) allait plus loin dans le continuum entre comportement fréquent et addiction. En effet, cette recherche évaluait différentes composantes de la CS chez des joueurs de JV et de JHA, en évaluant le niveau d'addiction et de fréquence de jeu en population générale. Cette étude a démontré, pour des sujets qui n'étaient pas des patients engagés dans des soins, des liens entre score de sévérité à l'addiction et capacité à reconnaître des émotions complexes chez les joueurs de JHA. Pour les joueurs de JV, les résultats de l'étude ont suggéré que les capacités de métacognition sociale pouvaient être altérées.

Enfin, les analyses préliminaires de l'étude BANCO sur les patients du service d'addictologie ont déjà permis de montrer un plus haut niveau d'alexithymie que les sujets contrôles. Cela rappelait ainsi l'importance d'évaluer via des auto-questionnaires le ressenti des patients concernant leur capacité à identifier leurs propres émotions.

Y a-t-il des points communs entre ACs ou avec les TUS ?

Concernant les compétences en CS des patients présentant un TUS, de nombreuses études ont été menées, et notamment auprès de patients présentant un trouble de l'usage de l'alcool. Les compétences en CS varieraient ainsi en fonction de l'objet de l'addiction (Quednow, 2020).

Il semblerait qu'un déficit de la capacité de reconnaissance des émotions existe dans tous les TUS, tout comme le suggère pour le JAP l'étude eSMILE, ou encore l'étude menée par Kornreich (Kornreich et al., 2016). Par ailleurs, une revue de littérature a retrouvé un profil similaire entre sujets dépendants à l'amphétamine et JVP sur la perception des rôles sociaux (Jiang et al., 2020). Ces différentes recherches évoquent la présence d'une altération sur ce point. L'étude BANCO2 et la suite de l'étude BANCO permettront de confirmer si ces difficultés sont présentes dans plusieurs ACs.

Concernant les capacités d'empathie émotionnelle, les résultats sont mitigés dans le trouble de l'usage de l'alcool (Dethier & Blairy, 2012; Grynberg et al., 2017). Pour les autres TUS, les études suggèrent une préservation de cette capacité pour le trouble de l'usage du cannabis (Quednow, 2020), des opioïdes (Kroll, Nikolic, et al., 2018) et des consommateurs de MDMA (3,4-methylenedioxyméthamphétamine) (Carlyle et al., 2019; Wunderli et al., 2017), et une altération dans le trouble de l'usage des stimulants (Y.-T. Kim et al., 2010; Kroll, Wunderli, et al., 2018) et de polysubstances (Kroll, Nikolic, et al., 2018). Il reste ainsi à mener différentes recherches pour confirmer ou infirmer l'absence d'altération des capacités d'empathie émotionnelle dans les ACs. Cela permettra de caractériser plus finement le profil de CS et étudier les points communs avec certains TUS.

Diverses études ont suggéré un déficit de la TdE dans le TUS, mais un questionnement subsiste concernant le fait que ce déficit soit lié à d'autres déficits cognitifs exécutifs ou bien un réel déficit de mentalisation (Quednow, 2020). La suite des analyses de l'étude BANCO pourra confirmer ou non l'absence d'altération de la TdE chez des patients avec un diagnostic de JAP. Si une différence entre ces patients et les participants contrôles apparaît sur la tâche de TdE, il sera important de contrôler l'impact du niveau exécutif sur la réalisation de cette tâche. En effet, le protocole BANCO inclut de nombreuses tâches cognitives qui évaluent un large panel de fonctions. Les analyses statistiques permettront d'évaluer l'impact du niveau cognitif sur la réalisation des tâches de TdE ce qui pourra faciliter la compréhension de l'origine de ce déficit s'il existe.

Concernant les capacités d'empathie cognitive ou théorie de l'esprit affective (Narme et al., 2010), l'utilisation de la LEAS (Lane et al., 1990) permettrait de définir plus précisément la qualité des

attributions d'émotions à soi et autrui dans les addictions. Dans cette tâche, 20 histoires sont présentées. Il est demandé à l'individu d'expliquer comment il se sentirait dans cette situation, mais aussi de dire ce que le second protagoniste de l'histoire ressent. La qualité de la réponse dépend de la complexité des émotions proposées, de leur diversité et multiplicité. Son utilisation a déjà démontré des scores plus bas, en comparaison à des sujets contrôles, pour les sujets avec un trouble du comportement alimentaire (Bydlowski et al., 2005) et pour les sujets avec un trouble de l'usage de l'alcool (Carton et al., 2010).

Enfin, selon certains auteurs, la prise de décision en situation sociale serait altérée dans le TUS, comme dans le JVP (Su et al., 2018). Or, dans ce travail de thèse, les analyses de l'étude eSMILE ne permettent pas de conclure à cette altération, même si d'autres recherches sont nécessaires pour mieux caractériser les capacités de prise de décision en situation sociale dans les ACs.

4.1.2. Implications cliniques et scientifiques de ces résultats

Utilisation des outils neuropsychologiques et des questionnaires : quid de l'empathie émotionnelle ?

Ce travail s'est attaché au maximum à mesurer les capacités de CS grâce à des tâches neuropsychologiques, mais aussi *via* des questionnaires. En effet, l'utilisation de ces deux types de méthodes d'évaluation permet d'avoir une vision globale et unifiée de nos patients (Jeong et al., 2020). Les tâches neuropsychologiques ont l'avantage de proposer une mesure standardisée et plus objective des compétences cognitives, tandis que les questionnaires permettent d'évaluer la subjectivité des individus. Cependant, chaque méthode possède des limites qui lui sont propres.

Par exemple, nous avons tenté d'évaluer les capacités d'empathie dans l'étude eSMILE, *via* un questionnaire et une tâche cognitive. L'analyse des réponses ne montrait pas de pattern de réponse particulier à la partie partage d'émotion (empathie émotionnelle) du MET-CORE en lien avec le score d'addiction, ni avec le niveau de difficulté rapporté par les sujets *via* le questionnaire IRI. Nos résultats suggéraient ainsi que les capacités d'empathie étaient préservées dans notre population. Or, une étude a démontré chez des patients présentant un diagnostic de JAP des scores moindres sur le questionnaire IRI sur les échelles de *Fantasy Scale* (FS) et de *Perspective Taking* (PT), et des scores plus haut sur l'échelle de *Personal Distress* (PD) (Tomei et al., 2017). Les échelles EC et PD reflèteraient les aspects affectif/émotionnels de l'empathie (capacité à partager une émotion), tandis que les échelles FS et PT traduiraient les niveaux d'empathie cognitive (comprendre l'expérience de l'autre) (Decety & Jackson, 2004; Gilet et al., 2013). Il semblerait donc dans cette étude que les patients avec un JAP rapportent des difficultés sur le plan de l'empathie cognitive, et aucune difficulté sur le plan de l'empathie affective. De manière intéressante, un pattern inverse d'altération (empathie affective altérée et empathie cognitive préservée) a été trouvé avec l'IRI dans un groupe de patients présentant un trouble de l'usage de l'alcool (Maurage, Grynberg, Noël, Joassin, Philippot, et al., 2011).

Nous avons donc cherché à voir s'il existait un lien entre nos deux mesures d'empathie. Nous voulions mieux comprendre l'absence de différence avec l'IRI sur notre étude mais aussi mesurer si les deux outils évaluaient deux concepts similaires pour les 103 participants de l'étude eSMILE. Pour cela, nous avons calculé les corrélations entre le score moyen au MET-CORE – partie partage d'émotion (empathie émotionnelle), et l'échelle IRI (et ses 4 sous-échelles). Il s'est avéré que le score moyen de partage d'émotion du MET-CORE était corrélé au score total de l'IRI, ainsi que plus particulièrement au score de l'échelle *Empathic Concern* (EC) ($p < 0.05$ pour les deux corrélations, respectivement $r=0.25$ et $r=0.22$). Pour rappel, l'échelle EC permet de refléter la capacité à ressentir de la compassion ou de l'inquiétude pour quelqu'un. Cela suggère qu'il existe bien un lien entre les deux outils, et que l'échelle EC mesure un concept associé au partage d'émotion mesurée par le MET-CORE comme l'empathie émotionnelle. Ces résultats rappellent par ailleurs l'importance des sous-scores dans les échelles.

De manière intéressante, l'échelle EC est l'unique échelle à ne pas montrer de différence entre les patients JAP et les contrôles dans l'étude de Tomei et al.. Les résultats de l'étude eSMILE semblent ainsi confirmer la préservation de cette capacité d'empathie affective comme relaté par Tomei et al. Cependant, proposer la tâche du MET-CORE et de l'IRI à des patients JAP permettrait de confirmer les résultats de notre étude mais aussi de celle de Tomei et al. En effet, si dans cette nouvelle étude les patients présentent des scores comparables à des sujets contrôles dans la partie partage d'émotions du MET-CORE ainsi qu'à l'échelle EC de l'IRI, cela sera un argument supplémentaire pour la préservation des capacités d'empathie émotionnelle dans le JAP. Cela permettra de guider le type de prise en charge à proposer. Enfin, il sera nécessaire de continuer à investiguer ces aspects pour mieux caractériser chez des patients le lien entre empathie et dans les autres ACs.

Pour finir, le MET-CORE a aussi été utilisé auprès d'un groupe de patients présentant un syndrome d'Asperger (Dziobek et al., 2008). Les résultats ont également démontré une altération des capacités d'empathie cognitive (identification correcte des émotions), et une préservation des capacités d'empathie émotionnelle. Il est ainsi intéressant de voir que le pattern de difficulté semble identique sur le plan de l'empathie entre des sujets avec une AC et des sujets diagnostiqués avec un trouble du spectre de l'autisme. Ces informations suggèrent des difficultés communes entre ces deux troubles et nécessitent de plus amples recherches. Par ailleurs, la prévalence de l'addiction à internet dans la population de patients avec un trouble du spectre de l'autisme s'élève à 10.8% (So et al., 2017). Des dysfonctions communes neuronales pourraient expliquer les patterns communs, et rappelle la possible comorbidité entre ces deux troubles et l'importance de les évaluer dans le cadre clinique, que ce soit dans la prise en charge de patients présentant une addiction ou ceux avec un trouble du spectre de l'autisme (van Wijngaarden-Cremers, 2014).

Particularités de l'évaluation cognitive des individus joueurs– Impact de la pratique du JV et du poker

Concernant l'évaluation de joueurs de JV, les résultats de nos études n'ont pas permis de conclure à la présence d'une altération du fonctionnement cognitif. En effet, dans l'étude eSMILE, nos participants étaient évalués en fonction de leur fréquence de JV. Or, la pratique du JV peut impacter positivement les capacités cognitives et notamment les JV d'action qui amélioreraient l'attention *top-down* (contrôle conscient de l'attention basé sur les expériences passées (Katsuki & Constantinidis, 2014)) et la cognition spatiale, voire la perception (Bediou et al., 2018).

En outre, sur le plan de la CS, des joueurs élités d'e-sport ont montré des réponses plus rapides lors de l'identification de stimuli sociaux en comparaison de joueurs non élités (Kang et al., 2020). Les joueurs de JV réguliers, voire professionnels, sont ainsi une population avec des caractéristiques neuropsychologiques particulières à prendre en compte lors de la construction de nos études. Cela peut par exemple aussi expliquer pourquoi certains auteurs rapportaient un plus haut niveau de compétence morale en lien avec la pratique des JV. Selon eux, jouer aux JV exposerait de manière régulière les joueurs à des dilemmes sociaux et leur permettrait d'améliorer cette compétence (Krcmar & Cingel, 2016; Sofia & Klimenko, 2019).

De manière analogue, il est extrêmement intéressant de s'intéresser au profil cognitif des joueurs de poker. En effet, les joueurs experts présentent aussi des caractéristiques cognitives particulières sur le plan du raisonnement, et notamment meilleures sur le plan de l'estimation de probabilités, que des contrôles ou des amateurs de poker (Zhu et al., 2022). Comme supposé dans l'étude PERHAPS, les joueurs de poker hors ligne, qu'ils soient experts ou non, s'appuient sur des informations sociales pour prendre des décisions et tenter de gagner de l'argent. Grâce aux données rapportées par les sujets, il a ainsi été suggéré que les performances au poker étaient liées à de meilleures capacités interpersonnelles alors que l'addiction était au contraire caractérisée par des difficultés sur ce plan (Schiavella et al., 2018).

Ainsi, ces deux types de populations (joueurs de poker professionnels et professionnels d'e-sport), qui présentent une pratique particulière par rapport à des joueurs amateurs (fréquence très élevée, avec le développement possible de compétences particulières), seraient des populations qui nous permettraient de construire des tâches d'évaluation de la CS pour diminuer l'effet plafond.

Importance clinique de la prise en charge neuropsychologique dans les ACs

Comme souligné dans la majorité des manuscrits, proposer de la RC apparaît essentiel dans la prise en charge des patients présentant une AC. Différentes études sur les ACs et la RC ont été citées tout au long de ce travail, notamment des études sur la modification du biais cognitif dans le JVP (Rabinovitz & Nagar, 2015) et le JAP (Boffo et al., 2017), ou encore une étude sur la modification de la régulation émotionnelle via un *serious game* dans le JAP (Tárrega et al., 2015). Dans d'autres populations, il a été démontré que la RC impactait positivement le fonctionnement psychosocial (Kurtz et al., 2016; Kurtz

& Richardson, 2012; Lahera et al., 2013), et l'alexithymie (Tchanturia et al., 2015). Enfin, l'amélioration des symptômes cliniques, obtenue via une prise en charge médicamenteuse (inhibiteurs de la recapture de la sérotonine), est accompagnée de l'amélioration du fonctionnement neurocognitif dans le JVP (Lim et al., 2016). Ces études ont démontré l'importance de la RC comme prise en charge en addition des traitements usuels. Par ailleurs, il est aussi important d'évaluer les compétences en CS, pour d'une part mieux caractériser les difficultés des patients, et d'autre part, essayer de mesurer objectivement les éventuels progrès suite à une prise en charge. En outre, des difficultés en CS peuvent aussi venir impacter la relation thérapeutique et ainsi augmenter le risque de rechutes (Quednow, 2020). Le cas clinique rapportant la prise en charge d'une patiente présentant un trouble de la communication social et un diagnostic d'AS ci-dessous permet d'illustrer ce point.

4.1.2.1. MANUSCRIT 6 : Cas clinique d'une patiente présentant un trouble de la communication sociale et une addiction sexuelle

4.1.2.1.1. Résumé du manuscrit 6

Le cas clinique rapporté dans l'article ci-après concerne une patiente (MC) présentant un trouble de la communication sociale (TCS) ainsi qu'un diagnostic d'AS. MC a été prise en charge au sein du service d'addictologie du CHU de Nantes et a donc pu bénéficier d'une évaluation clinique standardisée de son AS et des caractéristiques cliniques associées au sein de l'IFAC (Institut Fédératif des Addictions Comportementales), ainsi que d'un bilan neuropsychologique au sein du service du CRESERC (Centre de Référence en Soins d'Education thérapeutique et de Remédiation Cognitive).

La première évaluation confirmait le diagnostic d'AS, soulignait un haut niveau d'impulsivité ainsi qu'une faible estime de soi.

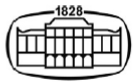
L'évaluation neuropsychologique montrait quant à elle la préservation du fonctionnement cognitif global (vitesse de traitement, aspects verbaux et visuospatiaux) ainsi qu'un profil attentionnel méticuleux. Le bilan neuropsychologique de la CS montrait aussi une préservation des capacités de reconnaissance des émotions, de fluences émotionnelles et TdE cognitive. Cependant, la patiente échouait sur les tâches de faux-pas, le RMET et la LEAS. Ces résultats suggéraient ainsi la présence de difficultés sur le plan de la TdE affective, de la conscience de ses propres émotions, et pour identifier une émotion lorsque moins d'informations sont présentes (comme sur le RMET).

La prise en charge de cette patiente a dévié du traitement usuel. En effet, il est habituellement proposé aux patients présentant une AS la participation à un groupe de TCC. Cependant, ce type de prise en charge nécessite de pouvoir évoluer dans un groupe et d'interagir de manière efficace, ce qui n'était pas possible pour MC. Nous avons donc proposé à la place à cette patiente de participer à un groupe SCIT (Social Cognition and Interaction Training), avec des patients présentant un diagnostic de schizophrénie. Ce groupe vise spécifiquement à travailler sur certaines composantes de la CS (perception des émotions, style d'attribution et TdE). Cette décision a été motivée par le fait que, de notre point de vue, les difficultés de MC concernant son comportement sexuel étaient principalement liées à une altération de ses capacités de CS. En effet, MC multipliait les prises de risque et les partenaires. L'interrogatoire clinique a permis de mettre en évidence que ces prises de risque étaient liées à une mauvaise compréhension de certaines situations sociales.

Après 6 mois de prise en charge, la patiente ne répondait plus aux critères de l'AS. Cependant, MC rapportait toujours des difficultés concernant la compréhension des normes sociales et des règles implicites des relations sociales malgré une amélioration dans le traitement des émotions et de la compréhension de certaines normes. Par ailleurs, la mère de cette patiente rapportait que ce groupe était un excellent exercice de socialisation et avait permis à sa fille de s'ouvrir et comprendre un peu mieux les difficultés que d'autres personnes pouvaient rencontrer.




Ce cas clinique illustre ainsi l'importance des capacités de CS dans le développement et le maintien des ACs, et notamment dans l'AS. Cet article met aussi en évidence la comorbidité possible entre AC et TCS et la possibilité de proposer de façon efficace des soins adjuvants ciblant la CS dans le traitement des ACs.





AKADÉMIAI KIADÓ

Social communication disorder and behavioural addiction: Case report and clinical implications

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4.1.2.1.2. Abstract

Background Social communication disorder (SCD) is a neurodevelopmental disorder that includes communication difficulties. Literature linking SCD and addictions is scarce, and there are only a few case reports regarding the co-occurrence of addiction and autism disorder spectrum, and only one of them addressed behavioural addictions.

Case presentation We report MC's case, who displayed an SCD and sexual addiction (SA). Clinical and neuropsychological evaluations suggested an alteration of social cognition, especially of affective theory of mind. This article also presents the adaptation made of the usual treatment.

Discussion This case report illustrates the importance of social cognition abilities in the development and maintenance of behavioural addictions, and specifically SA. It also highlights the possible comorbidity of these two disorders and the possibility to work on social cognition as an alternate therapy in the treatment of behavioural addictions.

Conclusions The co-occurrence of SCD and a behavioural addiction triggered clinical adaptations and implications that may affect a patient's treatment presenting one of these disorders.

Keywords social communication disorder – behavioural addiction – case report – sexual addiction – addictive disorder – neuropsychology



4.1.2.1.3. Background

The Diagnostic and Statistical Manual of mental disorders (DSM) newly included social communication disorder (SCD) in its fifth version (American Psychiatry Association, 2013). SCD concerns all patients presenting difficulties in using and understanding verbal and nonverbal communication that alter their daily life, without the presence of a disability or another mental disorder. For example, patients with SCD may experience difficulties using non-literal communication (irony, jokes) or respecting conversation codes. Restrained interests and repetitive behaviours cannot be present; otherwise, difficulties may be classified under autism spectrum disorder (ASD) (Swineford et al., 2014). ASD and SCD are both neurodevelopmental disorders that include communication difficulties.

It appears that ASD and addiction can co-occur (10.8% of the prevalence of internet addiction in an ASD group, (So et al., 2017), impacting the treatment. Indeed, as shown by the case report of van Wijngaarden-Cremers and van der Gaag (P. J. M. van Wijngaarden-Cremers & van der Gaag, 2015), a deficit in understanding social situations can lead patients to dangerous situations (sexual abuse and addiction to substances in this particular case report) because they attributed good intentions to others. Moreover, the usual treatment can be problematic because of the tendency of patients to interpret everything literally. However, few case reports linking ASD or SCD to addictions have been published. To our knowledge, only one of them was about a behavioural addiction (two cases of high functioning autism patients displaying a history of internet gaming addiction coupled with a gambling disorder or excessive sexual activity). The authors did not report any standardized measures (Wong, 2018).

In our case report, we present a co-occurrence between sexual addiction (SA) and SCD. SA is a disorder that

still needs further research to be included in the addiction sections of international classifications (Kraus et al., 2018) (Kraus et al., 2018). Nevertheless, compulsive sexual disorder has been added in the 11th of International Classification of Diseases (ICD-11) as an impulse control disorder (see Grubbs et al., 2020, for a history of the evolution of this concept). This diagnostic involves sexual activities being the main interest in the disinvestment of other spheres, a loss of control over the behaviour, and the cessation of sexual behaviour being impossible despite negative consequences and a lack of satisfaction (World Health Organization, 2018).

4.1.2.1.4. Case Presentation

Presentation of the patient

The patient gave her written consent for the description of her case. MC is a single 27-year-old woman who met several practitioners during her childhood for motor difficulties and struggles regarding novelty, for which neuroimaging did not show any alterations. After two failures to obtain her high school diploma and complaints regarding spatial orientation and relations to peers, new assessments were made. A genetic exploration highlighted a micro-deletion non-indexed in databases, the pathogenicity of which is uncertain. At the same time, neuropsychological evaluation excluded intellectual disability and showed difficulties in an advanced theory of mind task (the Reading the Mind in the Eyes Test, (Baron-Cohen et al., 2001)). Finally, at the age of 23, MC was diagnosed with SCD rather than ASD by a specialized center. Indeed, clinicians judged, based on her mother's information and several assessments, that stereotypies and restrained interests were absent from her developmental history.

After failing to obtain her high school diploma, MC began an adapted training to work in a resource center. She is currently living with her mother. As a teenager,



MC had preoccupations regarding sexuality and consulted erotic chat services in parallel with the difficulties presented above. At the beginning of her adulthood, she was registered on several meeting apps. When her mother discovered that MC was displaying a compulsive sexual behaviour, MC had had several sexual partners. She was willing to practice hardcore sex and to be filmed and posted on the internet. When discovering this situation, her mother confiscated her access to the internet. At this time, MC stopped her training.

Given the compulsive sexual behaviour and loss of control displayed by her daughter, MC was brought by her mother to our addictology department to explore an SA. Her complaints included fear of going outside because of what she could do, for example meeting new men via applications, or whom she could meet and difficulty distinguishing between men with good or bad intentions. Moreover, MC considerably doubted her ability to understand social relationships, and she addressed several letters to clinicians in this perspective.

Diagnostic assessment

As per the procedure in our department for all patients seeking treatment for a potential behavioural addiction, MC met the research team for a complete clinical evaluation in the framework of the EVALADD cohort

(NCT01248767) (see Table 29 for results and Fig. 9 for the timeline). The patient met the diagnostic criteria for SA. Moreover, the clinical assessment highlighted (i) the presence of an attention-deficit/hyperactivity disorder (ADHD), (ii) a high level of impulsivity, and (iii) a lack of self-esteem. Nevertheless, considering the clinical characteristics observed as the high level of impulsivity and difficulties encountered with social relationships, we chose to propose a neuropsychological assessment to objectify the patient's subjective information (see Table 30 for results).

This neuropsychological assessment showed that cognitive functioning was globally preserved (speed processing, verbal quotient, visuospatial abilities, and inhibition). Attention assessment showed a meticulous profile that can be linked with the patient's need to have precise answers regarding global social situations. This result also casts doubt on the diagnosis of ADHD identified with self-reports. Furthermore, the evaluation of social cognition did not show a deficit on every test, and MC succeeded in several tasks (emotion recognition, emotional fluencies, and cognitive theory of mind (i.e. attribution of mental states that are not emotions, such as beliefs)) (Shamay-Tsoory & Aharon-Peretz, 2007). Nevertheless, she failed the Eyes Test, the Faux Pas Task, and the LEAS (Levels of Emotional Awareness Scale).

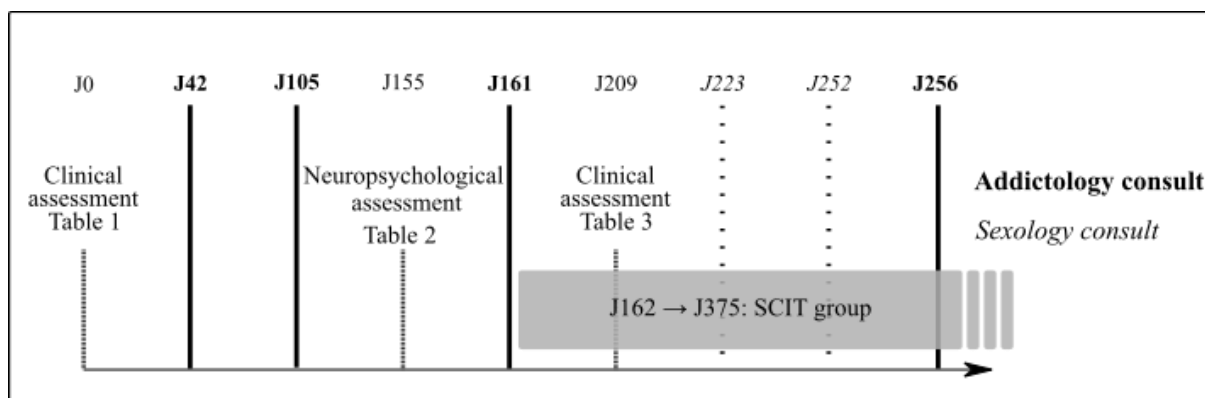


Figure 9 Timeline of the treatment of the patient - Manuscrit 6



Tableau 29 Clinical evaluation at the first visit - Manuscrit 6

Pathology explored	Measures	Results		
		Positive diagnosis	Period	Before or after the beginning of addiction
Psychopathological characteristics				
Axis 1 Psychiatric disorders	Mini-International Neuropsychiatric Interview (MINI) version 5.0 adapted for DSM-5 criteria (Lecrubier et al., 1997)	Major depressive episode	Current	After
		Suicidal risk	Current	After (in association with the addiction)
		Social phobia	Current	Before
		Post-traumatic stress disorder	Current	Before
Attention-Deficit/Hyperactivity Disorder (ADHD)	Wender Utah Rating Scale for Attention-Deficit/Hyperactivity Disorder in Adults (WURS-C) (Ward et al., 1993) Adult ADHD Self-Report Scale (ASRS-1.1) (Kessler et al., 2005)	86/100 (cut-off for the diagnostic: score \geq 46)		
		5/6 (cut-off for the diagnostic is a score \geq 4) Attention deficit: 33/36 Hyperactivity: 27/36		
Personality characteristics				
Attachment style	Relationship Scales Questionnaire (RS-Q) (Griffin & Bartholomew, 1994)	Secure: 2.6/5 Fearful: 2.4/5 Preoccupied: 3.4/5 Dismissing: 3.4/5		
Impulsivity	Impulsive Behavior Scale (UPPS-P) (Whiteside & Lynam, 2001)	Negative urgency: 14/16 Positive urgency: 10/16 Lack of premeditation: 11/16 Lack of perseverance: 8/16 Sensation seeking: 15/16		
Personality	Temperament and Character Inventory (TCI-125) (Cloninger et al., 1993)	<i>Temperaments:</i> Novelty seeking: 45/100 Harm avoidance: 85/100 Reward dependence: 80/100 Persistence: 80/100 <i>Characters:</i> Self-directedness: 36/100 Cooperativeness: 60/100 Self-transcendence: 33.3/100		
Self-esteem	Rosenberg Self-Esteem Scale (RSES) (Rosenberg, 2015)	19/40 (low)		
Quality of life	Satisfaction with Life Scale (SWLS) (Diener et al., 1985)	17/35 (slightly below the mean)		
Sexual addiction characteristics	Face-to-face interview exploring the diagnosis criteria proposed by Carnes and following the structure of the NODS (National Opinion Research Center DSM Screen for Gambling Problems) (P. Carnes, 2001; P. J. Carnes et al., 2014) Goodman criteria for Sexual Addiction (Goodman, 2001) Sexual Addiction Screening Test-Revised (SAST-R) (P. Carnes et al., 2010)	Exploration of the period before the cessation of the problematic behavior: score = 7/10 (cut-off score \geq 3)		
		8/9		
		Core item scale: 14/20 (cut-off is a score \geq 6) Internet items: 4/6 (cut-off is a score \geq 3) Men's items: 2/6 (cut-off is a score \geq 2)		



Factors triggering problematic behaviour

Women's items: 2/6 (*one item missing*, the cut-off is a score ≥ 2)
 Homosexuality items: 5/6 (cut-off is a score ≥ 2)
 Preoccupation: 2/4 (cut-off is score ≥ 2)
 Loss of control: 4/4 (cut-off is score ≥ 2)
 Relationship disturbance: 4/4 (cut-off is score ≥ 2)
 Affect disturbance: 3/5 (cut-off is score ≥ 2)
 Difficulties in relationships: 10/10
 Feeling positive emotions: 0/10
 Feeling negative emotions: 9/10
 Financial problems: 0/10
 Cash inflow: 0/10
 Context (place, people): 7/10
 Publicity: 8/10
 Substance use: 0/10

The Eyes Test is an advanced task for assessing the theory of mind because only eyes are presented, and the related emotions are not basic ones (unlike the emotion recognition task, which was successfully completed by MC). MC failed to recognize a faux pas situation during the test (which made her lose 6 points), and she also did not correctly answer 3 questions about the intentionality of the character and 2 questions regarding emotion attribution. Finally, during the LEAS, MC had difficulties answering questions about her feelings and could not answer questions about others' feelings. These results showed an alteration of the theory of mind, specifically for the emotional component. These outcomes specified the difficulties verbalized by MC in understanding the intentions of others.

Therapeutic intervention

MC went to addiction consultations once a month to every two months for the management of her problematic sexual behaviours (see Fig. 9 for the timeline). The patient also had two sexology consultations in our department. Moreover, we decided to deviate from the usual treatment, a cognitive, behavioural therapy (CBT) group. We created 10 years ago this CBT program dedicated to outpatients with a sex addiction. This program consists

of 10 weekly sessions lasting about 2 hours each, and involves 2 therapists for 10 patients. It aims at training to train patients throughout CBT strategies to regain control over sex behaviour. It combines motivational interviewing, psychoeducation regarding sex addiction and adaptive sexuality, stimulus control and response prevention strategies, cognitive restructuring, and relapse prevention techniques. However, the patient was included in a social cognition and interaction training (SCIT, (Combs et al., 2009) [bookmark13](#)) group. This therapeutic group, initially created for patients with schizophrenic disorders, consists of 24 weekly sessions of 1 hour 30 minutes and is focused on emotion perception, attribution style, and theory of mind. Its objective is to improve social cognition abilities and decrease social-cognitive biases in order to improve social functioning (D. L. Roberts et al., 2014). We chose to include her in this group, composed of patients with schizophrenia who also display alterations in social cognition, because, even if it took the appearance of SA, the observed problematic sexual behaviour was also, in our opinion, the reflection of social cognitive difficulties. This type of group does not require strong empathy skills, reading social cues, or interacting efficiently, as is the case for CBT groups, and it



maintains the advantage of a collective format and an opportunity to practise social skills. No medication was added to the treatment.

Tableau 30 Neurocognitive assessment - Manuscrit 6

Cognitive domain explored	Measures	Results
Processing speed (WAIS-4) (Wechsler, 2011)	Code	67, NS = 8
	Symbols	30, NS = 8
Premorbid intelligence	French version of the National Adult Reading Test (fNART) (Mackinnon & Mulligan, 2005)	23/40, z = 103, verbal quotient = 102
Visuospatial abilities	Taylor Complex Figure (E. M. Taylor, 1959)	36/36, type 1
	Visual Object and Space Perception Battery (VOSP) (Warrington & James, 1991)	<i>Object perception</i> Incomplete letters: 20/20 Silhouettes: 21/30 Object decision: 12/20 (cut-off = 14) Progressive silhouettes: 14/20 (cut-off = 15) <i>Spatial perception</i> Dot counting: 10/10 Position discrimination: 20/20 Number location: 10/10 Cube analysis tests: 10/10 20/20
Flexibility	PEGV (<i>Protocole Montréal Toulouse d'Evaluation des Gnosies visuelles</i> , a protocol that permits the evaluation of visual gnosis) (Agniel et al., 1992) Trail Making Test (TMT) (Lezak et al., 2004)	A : 42 s, B : 94 s ; delta = 52 s, percentile 5-10
Inhibition	Stroop test (Godefroy & GREFEX, 2008)	Denomination: 61 s, percentile 25 Read: 45 s, percentile 25 Interference: 89 s, percentile 50 Delta: 28, percentile 50-75
Visual selective attention	D2 test (Zimmermann & Fimm, 2002)	Number of items processed: Meticulous profile GZ: 367, Q1e* Number of error = 1, percentage of error F% = 0.3, Q1e Number of correct d ² crossed, KL = 155, Q1
Social cognition	Facial Emotion Recognition (mini-SEA) (Ehrlé et al., 2011) Faces Test (Etchepare et al., 2014)	31/35 (loses 1 point for fear, disgust, neutral and anger), z = - 0.3 Denomination without clues: 4/10 simple emotions, 2/10 complex ones. Total: 6/20: z = - 1.1 Fixed choice: 8/10 on simple emotions, 10/10 on complex ones
	Eyes Test (Baron-Cohen et al., 2001)	16/36: z = - 3.25 <i>The patient always chose the hostile item when proposed.</i>



Emotional fluences	18 words (<i>completed right after Faces Test; the patient was cued</i>)
False beliefs (TOM-15) (Desgranges et al., 2012)	1st order: 8/8 Total = 13/15, $z = -1.1$ FC1, 16 min <i>The patient relied on the</i> 2 nd order 5/7, 6 min <i>logic of the story and</i> Control <i>intellectualized answers,</i> questions: <i>going against her</i> 15/15, 2 <i>spontaneous choice.</i> minutes 19 s
Attribution intention (Brunet et al., 2003)	12 good answers, 1 absurd and 1 possible Control questions: 27/28
<i>Faux pas</i> (theory of mind, mini SEA) (Bertoux et al., 2012)	19/30 Detection $z = -1.55$ of <i>faux pas</i> 20/20 non-faux pas stories 10/10 control questions
LEAS (Levels of Emotional Awareness Scale) (Bydlowski et al., 2002)	Points for feelings of the patient: 37, $z = -3.45$ <i>No answer was given regarding the others' feelings</i>
Alexithymia (TAS-20) (Loas et al., 1995)	78 (<i>cut-off is a score ≥ 56</i>)

**Q1e = Extreme first quartile*

Follow-up and outcomes

After six months of treatment, MC did not show SA's criteria (see Table 31 for the follow-up clinical evaluation). Nevertheless, MC was still questioning social norms and tried to understand the implicit rules of social relationships. The patient also felt that the situation was a dead end. Regarding the SCIT group, her mother, who took the role of practice partner (i.e. the identified person who works with the patient during the week on SCIT exercises), related that the group was an excellent socialisation exercise for her daughter. She also noticed that MC was less in her bubble and more aware of the difficulties that other patients could meet. This improvement seems to reflect social cognitive abilities enhancement thanks to the group situation and exercises proposed in the SCIT group.

Patient perspective

After her treatment, MC noticed an easier processing of emotions, as well as a better understanding of certain social norms. Nevertheless, implicit information was still complex for her to understand.

4.1.2.1.5. Discussion

This case report shows the importance of taking into account social cognition in treating patients with behavioural addictions and, more specifically, SA. Indeed, in MC's case, social cognitive alterations in the framework of her SCD led her to misunderstand certain social situations and accept several risky sexual situations without protecting herself. Nevertheless, our patient also displayed clinical signs of addiction, such as craving and the urge to perform the behaviour, which seemed to indicate that the sexual situations were not only abuses of her vulnerability.



Tableau 31 Clinical evaluation after 6 months of treatment - Manuscrit 6

Pathology explored	Tool used	Results	Comparison with the first assessment
Psychopathological characteristics			
Attention-Deficit/Hyperactivity Disorder	Adult ADHD Self-Report Scale (ASRS-1.1)	<i>4 items with missing data on the six first items</i> Attention deficit: 18/32 (<i>4 missing data</i>) Hyperactivity: 25/36	Diminution on both scales, especially on the attention deficit scale
Personality characteristics			
Attachment style	Relationship Scales Questionnaire (RS-Q)	Secure: 2.4/5 Fearful: NK/5 Preoccupied: NK/5 Dismissing: NK/5	Slight diminution on the secure scale
Impulsivity	Impulsive Behavior Scale (UPPS-P)	Negative urgency: 12/16 Positive urgency: 10/16 Lack of premeditation: NK/16 Lack of perseveration: 8/16 Sensation seeking: 8/16	Diminution of scales regarding negative urgency and sensation seeking
Personality	Temperament and Character Inventory (TCI-125)	<i>Characters:</i> Self-directedness: NK/100 Cooperativeness: NK100 Self-transcendence: NK/100	
Self-esteem	Rosenberg Self-Esteem Scale (RSES)	18/40 (low)	Decrease of one point, no improvement in self-esteem
Quality of life	Satisfaction with Life Scale (SWLS)	<i>One missing item</i> 12/28 (slightly below the mean)	No significant change of satisfaction with life

	Face-to-face interview exploring the diagnosis criteria proposed by Carnes and following the structure of the NODS (National Opinion Research Center DSM Screen for Gambling Problems)	Exploration of the actual period: score = 1/10 (cut-off score ≥ 3)	Absence of sexual addiction diagnostic
	Goodman criteria:	Non-validated	
Sexual addiction characteristics	Sexual Addiction Screening Test-Revised (SAST-R)	<p>Core item scale: 10/20 (cut-off is a score ≥ 6)</p> <p>Internet items: 1/5 (one item missing, cut-off is a score ≥ 3)</p> <p>Men's items: 0/6 (cut-off is a score ≥ 2)</p> <p>Women's items: 0/5 (one missing item, cut-off is a score ≥ 2)</p> <p>Homosexual items: 0/4 (two items missing, cut-off is a score ≥ 2)</p> <p>Preoccupation: 1/4 (cut-off is score ≥ 2)</p> <p>Loss of control: 4/4 (cut-off is score ≥ 2)</p> <p>Relationship disturbance: 1/2 (two items missing, cut-off is score ≥ 2)</p> <p>Affect disturbance: 2/4 (one item missing, cut-off is score ≥ 2)</p>	Improvement of addictive symptoms
	Factors triggering problematic behaviour	<p>Difficulties in relationships: 0/10</p> <p>Feeling positive emotions: 0/10</p> <p>Feeling negative emotions: 0/10</p> <p>Financial problems: 0/10</p> <p>Cash inflow: 0/10</p> <p>Context (place, people): 0/10</p> <p>Publicity: 0/10</p> <p>Substances use: 0/10</p>	No additional factor that triggers the problematic behaviour



For the specific case of MC, the SCD may have favoured the appearance and maintenance of SA. Moreover, as the standard treatment for SA (CBT group) could not be proposed to MC, the therapeutic strategy was to work on social cognition. This upstream focus permitted us to work on social abilities, which led her to better understand other's intentions (thanks, for example, to the theory of mind and emotion perception exercises). This helped her protect herself, thanks to a better understanding of situations that can be dangerous.

This case also suggests commune alterations between SCD and addiction. Indeed, MC's neuropsychological assessment identified an alteration of affective theory of mind, which relies on the ventromedial prefrontal cortex (S. G. Shamay-Tsoory & Aharon-Peretz, 2007). This part of the prefrontal cortex has also been linked to hot executive functioning and decision-making in addiction models (Noël et al., 2013). Therefore, it seems that common neurobiological alterations could explain the comorbidity observed in this case report. Thus, it seems essential to screen for social cognitive disabilities in patients who present addiction and complain of social difficulties. Indeed, even if there is no formal deficit in social communication, therapy focused on the remediation of social cognition could be a therapeutic alternative that can also improve addictive symptoms.

4.1.2.1.6. Conclusion

This case report highlights the importance of social cognition abilities in the initiation, development, and

maintenance of addictive behaviours. It also shows the link between addiction and social cognition alterations and the importance of assessing patients' social cognition with addictions and clinical signs of addiction for patients presenting alterations of social cognition.

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Author's contribution

EH, MGB, GCB, and MCE are responsible for the conceptualization of the article. MV performed the neuropsychological evaluation. EH wrote the original draft, and MGB, MCE, MV, and GCB reviewed and edited the paper.

Conflict of interest:

The authors declare no conflicts of interest.

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Les références sont incluses dans l'annexe Références du document complet.



Ce dernier manuscrit est un nouvel argument concernant la nécessité d'investiguer les aspects sociaux lorsque l'on rencontre des patients présentant une AC (reconnue ou non par la littérature internationale). En effet, ce cas clinique illustre ainsi la possibilité de prendre en charge de façon ciblée des difficultés en CS, contribuant à améliorer en retour les symptômes de l'addiction.

De plus, ce cas clinique expose aussi l'importance des difficultés de CS dans la prise en charge de patients présentant une AC. Ces difficultés sont propres au TCS, mais sont aussi essentiels dans le trouble du spectre autistique. Cet article soulève l'intérêt de pouvoir évaluer de manière systématique la présence de difficultés sur le plan de la CS pour tous les patients présentant une AC mais aussi la présence de trait autistiques. Dans ce dernier cas, questionner de manière systématique les difficultés sur le plan social et des facilités plutôt sur le plan logique ou visuo-perceptif peut être une première approche, et peut permettre de soulever des pistes thérapeutiques qui ne seraient apparues que plus tard au cours de la prise en charge. Un auto-questionnaire tel que l'*Autism Quotient* (Baron-Cohen et al., 2001) peut par exemple être utilisé.

4.2.Limites

Chacune des études réalisées dans le cadre de ce travail de thèse présente des limites.

Lien avec les caractéristiques cliniques

Tout d'abord, il est important d'intégrer de façon systématique dans toute évaluation des capacités cognitives en CS des mesures du fonctionnement cognitif global (intelligence prémorbide, attention), comme effectué dans l'étude BANCO (fNART) et PERHAPS (MMSE). En effet, les capacités de CS peuvent être impactées par le niveau exécutif (Quednow, 2020) même si ces compétences semblent être un construit différent du fonctionnement neurocognitif (Etchepare & Prouteau, 2017). L'étude eSMILE ne comprenait pas de mesure du fonctionnement cognitif attentionnel ou exécutif. Il aurait été intéressant dans cette étude de proposer ce type de mesure pour contrôler ces capacités pour améliorer la compréhension et l'analyse de nos résultats.

Par ailleurs, il semble important de prendre en compte le genre dans l'évaluation des capacités cognitives en CS. L'étude PERHAPS n'incluait que des hommes, et ne permettait donc pas de tirer de conclusion quant aux particularités féminines. Dans l'étude BANCO, la poursuite des inclusions permettra probablement d'inclure des femmes et d'observer si des différences ou particularités de genre peuvent être mises en évidence dans le groupe de JAP sur le plan neurocognitif. Enfin, les analyses d'eSMILE n'incluent pas l'effet du genre, or, il semblerait que les femmes présentent des niveaux d'empathie plus élevés (Gilet et al., 2013). Il serait donc important de pouvoir effectuer une nouvelle fois les analyses en prenant en compte ce facteur.

Aspects méthodologiques

Comme exposé lors de la revue de littérature sur le JV, et qui est aussi visible sur l'étude de la CS dans les TUS, la multiplicité des outils utilisés et des populations évaluées est un réel frein pour tirer des conclusions et généralités au sujet des compétences en CS de patients présentant une addiction. Cette limite est liée au fait d'une part que l'AC est un sujet d'étude relativement récent, et d'autre part que la CS a surtout été étudiée dans le trouble du spectre autistique et la schizophrénie. Ces études ont permis de générer des modèles propres à ces troubles, sans qu'il n'existe de consensus général ou propres aux addictions qui permettent de savoir comment évaluer la CS. La construction de tâches plus spécifiques peut être une piste de recherche pour mieux appréhender des difficultés fines, tout en balayant un large spectre de fonctions incluses dans la CS.

Par ailleurs, l'utilisation de designs transversaux et non longitudinaux ne permet pas de caractériser la direction du lien entre difficultés de CS et addiction. Des questions subsistent ainsi toujours concernant l'apparition des altérations : est-ce qu'une altération primaire des capacités à traiter les informations sociales va engendrer l'augmentation des pratiques problématiques du fait de difficultés dans la vie quotidienne, ou bien la répétition du comportement va impacter négativement certains aspects de la CS ? De nouvelles études sont ainsi nécessaires pour mieux comprendre cette direction, avec des études longitudinales par exemple, ou encore en étudiant des populations à haut risque de développer une addiction (en s'appuyant sur les différents facteurs de risque connus).

Par ailleurs, mener une étude longitudinale sur le lien entre capacités cognitives et caractéristiques de l'addiction (sévérité, rechute, rétablissement...) permettrait par exemple d'observer l'impact du fonctionnement cognitif sur la prise en charge. Cela pourrait être réalisé via des évaluations systématiques du fonctionnement cognitif en début de prise en charge et au cours et/ou à distance du suivi.

D'autre part ce type d'étude permettrait de répondre aux questions concernant le lien de causalité entre CS et développement et maintien de l'AC. En effet, dans une étude idéale, il serait possible d'évaluer un groupe de sujets en population à risque dans un premier temps et d'observer à plusieurs temps ensuite, si certaines variables du fonctionnement cognitif permettent de prédire des difficultés sur le plan des addictions. Cependant, pour réaliser ce type d'études, il est tout d'abord nécessaire d'acter quelles composantes pourraient être altérées.

4.3.Perspectives

Les limites soulevées par ce travail de thèse permettent d'envisager de futurs travaux en lien. En premier lieu, l'étude des trajectoires des patients pourra s'effectuer à la suite de l'étude BANCO et BANCO2. En effet, tous les patients recrutés sont issus de la cohorte EVALADD, qui évalue de manière

systématique les comorbidités et les caractéristiques de l'addiction en début de prise en charge, puis à 6 mois et enfin tous les ans. Les données issues des protocoles BANCO et BANCO2 pourraient ainsi être utilisés pour évaluer si une ou plusieurs tâches cognitives (incluant des tâches de CS) peuvent prédire, ou expliquer, les trajectoires de rétablissement ou de rechute dans les ACs à quelques mois, voire quelques années plus tard.

Par ailleurs, un centre expert spécialisé dans les troubles du comportement alimentaire a été ouvert il y a peu au sein du service d'Addictologie du CHU de Nantes. Ce centre offre la possibilité de réaliser des évaluations neuropsychologiques systématiques, incluant les tâches de CS et faisant le lien avec les données de la cohorte EVALADD. L'étude de l'impact du fonctionnement cognitif pourra être effectuée en lien avec ces données et notamment via la LEAS. En outre, ce centre pourra proposer un dépistage des traits autistiques systématique pour permettre d'évaluer la prévalence de ce trouble dans cette population spécifique, et les professionnels pourront se former au repérage et au dépistage de cette comorbidité.

Enfin, de la RC est proposée aux patients suivis dans ce nouveau service. Ce groupe de RC pourra par la suite être proposé également à des patients présentant un diagnostic de JVP ou de JAP. A plus long terme, construire une prise en charge standardisée, ainsi qu'une évaluation systématique avant et après la prise en charge groupale, permettrait d'évaluer sur différents groupes et types de patients, l'effet de la RC, en fonction des profils. Cela pourrait aussi participer à l'amélioration de la prise en charge des patients présentant une AC en évaluant son efficacité, et en déterminant le type de patients qui pourraient le plus bénéficier de ce type de prise en charge.

Conclusion

Ce travail de thèse a permis d'explorer de manière systématique la littérature sur le JAP et le JVP et la CS. Tout en démontrant la rareté des études, nous avons cherché à mieux appréhender le lien entre répétition du comportement, addiction et CS grâce à 3 études auprès de joueurs avec ou sans addictions. Ces recherches ont confirmé la présence d'un traitement particulier des informations sociales, voire de difficultés sur le plan de la reconnaissance des émotions faciales pour le JAP et de la métacognition pour le JVP. De nombreuses recherches restent à être menées, grâce à divers outils neuropsychologiques mais aussi statistiques.

Annexes

Liste des annexes

Annexe 1 : Liste des abréviations

Annexe 2 : Références

Annexe 3 : Données supplémentaires de l'article concernant les analyses de régression de l'étude eSMILE

Annexe 3 : Données supplémentaires issues de l'article décrivant les protocoles BANCO et BANCO2

Annexe 1 : Liste des abréviations

AA	addiction à l'alimentation
ACP	analyse en composante principale
AC(s)	Addiction(s) comportementale(s)
AIC	<i>Akaike Information Criterion</i>
AVGP	Action videogame players
AS	addiction sexuelle
ASRS	<i>Adult ADHD Self-Report Scale Symptom Checklist</i>
BANCO	<i>Behavioral Addictions and related NeuroCOgnitive aspects</i>
BA(s)	<i>Behavioral Addiction(s)</i>
BDI-13	<i>13-item Beck Depression Inventory</i>
BIC	<i>Bayesian Information Criterion</i>
CG	<i>Control Group</i>
CG	<i>Chicken Game</i> (dans l'étude eSMILE)
CIM	Classification internationale des maladies
CG	<i>Control Group</i>
CG	<i>Chicken game</i>
CPGI	<i>Canadian Problem Gambling Index</i>
CPP	Comité de Protection des Personnes
CREST	<i>Cognitive Remediation and Emotion Skills Training</i>
CRT	Competitive Reaction Task
CS	Cognition sociale
DDE	<i>Difficulty In Describing One's Own Emotions</i>
DIF	<i>Difficulty In Identifying Emotions</i>
DSM	Manuel diagnostique et statistique des troubles mentaux <i>Diagnostic and Statistical Manual of mental disorders</i>
EC	<i>Empathic Concern scal</i>
EEG	Electroencephalogram
EET	<i>Emotion Evaluation Test</i>
EDI-2	<i>Eating Disorders Inventory-2</i>
EQI	<i>Emotional Quotient Inventory</i>

Annexe 1 : Liste des abréviations

EQI YV	<i>Emotional Quotient Inventory Youth Version</i>
EMG	<i>Electromyography</i>
EPG	<i>Esport Players Group</i>
EOT	<i>Externally Oriented Thinking</i>
ER-40	<i>Penn Emotion Recognition Task</i>
ERPs	<i>Event-Related Potentials</i>
eSMILE	<i>onlinE aSsessMent of socIaL cognition of gamErs and gamblers</i>
FA	<i>Food Addiction</i>
FAB	<i>Florida Affect Battery</i>
FDJ	<i>Française des Jeux</i>
fNART	<i>French Version of the National Adult Reading Test</i>
fMRI	<i>functional Magnetic Resonance Imaging</i>
FPS	<i>First Person Shooter</i>
FS	<i>Fantasy scale</i>
GAM	<i>General Aggression Model</i>
GAS7	<i>7-item Game Addiction Scale</i>
Gb	<i>gamblers</i>
GbD	<i>Gambling Disorder</i>
GD	<i>Gambling Disorder dans le premier manuscrit</i> <i>Gaming disorder dans le second</i>
Gm	<i>gamers</i>
GmD	<i>Gaming Disorder</i>
GNEDS	<i>Groupement Nantais d’Ethique dans le Domaine de la Santé</i>
HAD	<i>Hospital Anxiety And Depression Scale</i>
HCS	<i>Healthy Controls</i>
HGB	<i>High-Frequency Gambling Group</i>
HGM	<i>High-Frequency Gaming Group</i>
IAT	<i>Internet Addiction Test</i>
ICD	<i>International Classification of Disease</i>
ICJE	<i>Indice Canadien du Jeu Excessif</i>
IDR	<i>Inhibition de retour</i>

Annexe 1 : Liste des abréviations

IGD	<i>Internet Gaming Disorder group</i>
IGDS9-SF	<i>Nine-Item Short-Form Scale To Assess Internet Gaming Disorder</i>
IGT	<i>Iowa Gambling Task</i>
IGDT	<i>Internet Gaming disorder Test</i>
IGDT10	<i>Ten-item Internet Gaming Disorder Test</i>
IFAC	Institut Fédératif des Addictions Comportementales
IOR	<i>Inhibition of Return</i>
I-PACE	<i>Interaction of Person-Affect-Cognition-Execution</i>
IPT-15	<i>Interpersonal Perception Task</i>
IRI	<i>Interpersonal Reactivity Index</i>
JAP	Jeu D'argent Pathologique
JHA	Jeux De Hazard Et D'argent
JV	Jeux vidéo
JVP	Jeux Vidéo Pathologique
KDEF	<i>Karolinska Directed Emotional Faces</i>
LEAS	<i>Levels of Emotional Awareness</i>
LGB	<i>Low-Frequency Gambling Group</i>
LGM	<i>Low-Frequency Gaming Group</i>
MAGS-DSM-IV	<i>Massachusetts Gambling Screen</i>
MCT	<i>Moral Competency Test</i>
MET-CORE	<i>Condensed and revised Multifaced Empathy Test</i>
MeSH	<i>Medical Subject Headings</i>
MD	<i>Methamphetamine Group</i>
MIDI	<i>Minnesota Impulsive Disorder Interview</i>
MINI	<i>Mini International Neuropsychiatric Interview</i>
Mini-SEA	<i>Mini Social and Cognition and Emotional Assessment</i>
MMORPGs	<i>Massively Multi- Player Online Role-Playing Games</i> Jeux de rôle en ligne massivement multi-joueurs
MMR	<i>Match Making Rating</i>
MMSE	<i>Mini Mental State Examination</i>
MOBA	<i>Multiplayer online battle area</i>

Annexe 1 : Liste des abréviations

mPFC	<i>medial PreFrontal Cortex</i>
M-WCST	<i>Modified Wisconsin Card Sorting Test</i>
NC	<i>Normal Control Group</i>
NODS	<i>National Opinion Research Center DSM-IV Screen for Gambling Problems</i>
NVGP	<i>Non videogame players</i>
OIGU	<i>Occasional Internet Game Use</i>
PBAMS/NBAMS	<i>Positive/ Negative Behavioral Addiction Metacognition Scale</i>
PBG	<i>Pro-Baseball Group</i>
PCA	<i>Principal Component Analysis</i>
	<i>Personal Distress scale</i>
PD	<i>Prisoner's dilemma dans le manuscrit 2</i>
PERHAPS	<i>PokER, HAbiletés et Problèmes aSsociés</i>
PEP	<i>Computerized test of primary emotions perception</i>
	<i>Pathological Gambling</i>
PG	<i>Pathological/problematic gaming dans le manuscrit 2</i>
PGSI	<i>Problem Gambling Severity Index</i>
PIGU	<i>Problematic Internet Game Use</i>
PIUQ-JV	<i>Problematic Internet Use Questionnaire</i>
PMU	<i>Pari Mutuel Urbain</i>
PRISMA	<i>Reporting Items for Systematic Review and Meta-Analyses</i>
PRO	<i>Patient- Reported Outcomes</i>
PT	<i>Perspective Taking scale</i>
RC	<i>Remédiation cognitive</i>
RC2S	<i>Cognitive Remediation of Social Cognition in Schizophrenia</i>
RMET	<i>Reading the Mind in the Eyes Task</i>
RPG	<i>Role Playing Game</i>
RPPG	<i>Regular Nondisordered Poker Players</i>
RSES	<i>Rosenberg Self-Esteem Scale</i>
RT	<i>Reaction Times</i>
RTS	<i>Real-Time Strategy</i>
SA	<i>Sexual Addiction</i>

Annexe 1 : Liste des abréviations

SAST-R	<i>Sexual Addiction Screening Test-Revised</i>
SCIT	<i>Social Cognition and Interaction Training</i>
SOA	<i>Stimulus-Onset Asynchrony</i>
STAI-YB	<i>trait version of the State-Trait Anxiety Inventory</i>
SC	<i>Superior Colliculus dans manuscript 3(Social Cognition</i>
SCIT	<i>Social Cognition and Interaction Training</i>
SD	<i>Standard Deviation</i>
SKIP	<i>Single Key Impulsivity Paradigm</i>
SOGS	<i>South Oaks Gambling Screen</i>
SPIRIT	<i>Standard Protocol Items: Recommendations for Interventional Trials</i>
SST	<i>Stop Signal Task</i>
TAS-20	<i>Toronto Alexithymia Scale</i>
TCC	<i>Thérapie cognitive-comportementale</i>
TCI-125	<i>Temperament and Character Inventory</i>
TCRTT	<i>Taylor Competition Reaction Time Task</i>
TdE	<i>Théorie de l'esprit</i>
T.h.o.m.a.s	<i>Theory Of Mind Assessment Scale</i>
TMT	<i>Trail Making Test</i>
ToM	<i>Theory Of Mind</i>
TUS	<i>Trouble de l'usage de substances</i>
UPPS-P	<i>Impulsive Behavior Scale</i>
VDP	<i>Visual Probe Detection Task</i>
VGH	<i>Violent Game Habits</i>
VVG	<i>Violent VG</i>
VVGE	<i>Violent VG Exposure</i>
VMPFC	<i>Ventromedial Prefrontal Cortex</i>
YIAT	<i>Young Internet Addiction Test</i>
YFAS	<i>Yale Food Addiction Scale</i>
WAIS-IV	<i>Wechsler Adult Intelligence Scale</i>
WLR	<i>Win Loss Ratio</i>

WURCS- *Wender Utah Rating Scale–short version*

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Annexe 3 : Données supplémentaires de l'article concernant les analyses de régression de l'étude eSMILE

Tableau 32 Regression analysis - Supplementary data - Manuscrit 5

Dependant variables	Variables included in the model	p value of the model	p value of the comparison on with the first model (LRT)	AIC	(BIC)
ER40					
Number of errors on sad faces	Mean number of hours played for gamers	0,042		152,431	158,106
	Mean number of hours played for gamers + TAS20 total score	0,124	0,769	154,339	161,906
Number of errors on sad faces with low intensity	Mean number of hours played for gamers	0,103		113,013	118,689
	Mean number of hours played for gamers + TAS20 total score	0,240	0,639	114,779	122,346
Number of errors on extreme intensity faces	Score on the IGTD10	0,012		145,264	150,939
	Score on the IGTD10 + TAS20 total score	0,020	0,205	145,581	153,148
MET-CORE					
Number of errors	Score on the CPGI	0,012		301,117	307,193
	Score on the CPGI + TAS20 total score	0,032	0,412	302,412	310,513
	Score on the CPGI (without missing values from variables below)	0,014		291,931	297,898
	Score on the CPGI (without missing values from variables in the model) + Mean number of hours played	0,027	0,260	292,602	300,558
Number of errors on positive pictures	Mean number of hours played for gamers	0,026		179,032	184,708
	Mean number of hours played for gamers + TAS20 total score	0,085	0,890	181,012	188,579
Number of errors on negative pictures	Mean number of hours played for gamblers	0,508		249,056	255,023
	Mean number of hours played + TAS20 total score	0,805	0,992	251,056	259,012
	Score on the CPGI	0,007		249,691	255,767
	Score on the CPGI + TAS20 total score	0,021	0,497	251,206	259,307
	Mean number of hours played for gamblers + Score on the CPGI	0,012	0,002	242,093	250,049
Metacognition scores					
<i>After the ER-40 task</i>	Score on the IGTD10	0,057		96,56	102,05
	Score on the IGTD10 + TAS20 total score	0,120	0,42	97,86	105,17
<i>Before the MET-CORE</i>	Number of errors on positive pictures	0,257		76,49	81,98
	Number of errors on positive pictures + TAS20	0,474	0,64	78,25	85,57
<i>After the MET-CORE</i>	Rating total for gamers	0,005		90,27	95,76
	Rating total for gamers + TAS20 total score	0,002	0,03	87,47	94,78
	Rating of negative pictures for gamers	0,003		89,43	94,91
	Rating of negative pictures for gamers + tAS20 total score	0,004	0,10	88,65	95,97
	CPGI score	0,447		127,46	133,37

Annexe 3 : Données supplémentaires - eSMILE

<i>Before the CG task</i>	CPGI score + TAS20 total score	0,751	0,97	129,46	137,34
	Number of cooperative choices with the other player for gamblers	0,001		116,76	122,67
<i>After the CG task</i>	Number of cooperative choices with the other player for gamblers + TAS20 total score	0,005	0,80	118,69	126,58
	Number of cooperative choices with the other player for gamblers	0,110		163,44	169,35
	Number of cooperative choices with the other player for gamblers + TAS20 total score	0,231	0,52	165,01	172,89
	Number of cooperative choices for gamers	0,022		150,98	156,47
	Number of cooperative choices for gamers + TAS20 total score	0,069	0,67	152,79	160,11
	Number of cooperative choices with the computer for gamers	0,047		152,33	157,82
	Number of cooperative choices with the computer for gamers + TAS20	0,108	0,45	153,73	161,04

LRT = Likelihood Ratio Test; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion. Indicators of the better model are in bold (significant p value, minimum AIC and BIC).

Annexe 3 : Données supplémentaires – BANCO & BANCO2

Annexe 4 : Données supplémentaires issues de l'article décrivant les protocoles BANCO et BANCO2

Supporting files

Labels of supporting files:

- Supporting file 1: Stimulus materials (pictures and words)
- Supporting file 2: Apparatus of the study
- Supporting file 3: Details on the cognitive tasks

References of all supporting files are included in the list of reference in annex 1.

S1: Stimulus materials (pictures and words)

Procedure for the picture selection

Regarding addiction-related pictures, a preliminary study (unpublished work) was conducted with patients presenting with a BA and controls recruited through the network of the research team without BA (54 patients and 53 controls). For each type of addiction (gambling disorder (GbD), gaming disorder (GmD), sexual addiction (SA) and food addiction (FA)), a preselection of 60 addiction-related pictures and 30 neutral pictures (used only as distractors) in “Google Images” was conducted. The participants rated each picture for the emotional valence and arousal using the SAM scale (Self-Assessment Manikin, a Likert scale with nine levels (M. M. Bradley & Lang, 1994)), as well as the level of connection with addiction using a 9-point Likert scale.

Pictures with a low level of connection with addiction (score < 5) were removed from the picture set. Then, the pictures were ranked according to their connection with addiction, their arousal, and their valence, in this order. Finally, for each addiction, the ranked pictures were sorted depending on the preferred modality of the addiction depicted in it (see Table 33 for a detail of available modalities for each addiction). In the end, the picture set included the six pictures most related to addiction for each modality to be able to present twelve different pictures related to addiction for each task in the BANCO and BANCO2 studies. Indeed, the participants have to choose two modalities that reflect his/her preferences. The only exception is for FA with which the participant has to choose only one modality. As a consequence, the picture set is composed of twelve pictures of salted food, twelve pictures of sugar food, or a mix of six of each (twelve in sum) for the combined modality.

Each addiction-related picture is paired with a positive, a negative, and two neutral pictures. Neutral, positive, and negative pictures come from the IAPS database (International Affective Picture System) (Lang et al., 2008). Positive and negative pictures are defined by a valence ranging from 6 to 9 and from 1 to 4, respectively, while neutral pictures correspond to pictures with a valence ranging from 4 to 6. For the positive pictures, those with the highest valence and with high arousal (>4) are favoured. For negative pictures, those with the lowest valence and with high arousal (>4) were favoured. Finally, for neutral pictures, those with the lowest arousal and the valence closest to 5 were favoured (see Additional Table 33 for characteristics). Neutral, positive, and negative pictures that included an element that can be related to addiction were excluded (e.g., for gambling: all pictures with horses, sports, or money). These pictures were matched with the addiction-related pictures based on the presence of faces, hands, animals, and actions and the global composition of the picture.

Tableau 33 Arousal and valence of picture stimuli - Supplementary data - Manuscrit 5

Addiction stimuli		Neutral stimuli		Positive stimuli		Negative stimuli	
Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal

	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>	Mean <i>Min-Max</i>
GbD	4,87 2,29 - 6,17	4,52 3,00 - 6,96	5,08 4,06 - 5,8	3,02 1,05 - 3,95	7,32 6,32 - 8,03	5,15 4,28 - 6,28	2,56 1,66 - 3,49	6,15 4,57 - 7,35
GmD	5,88 3,60 - 7,00	5,48 4,00 - 6,33	5,15 4,06 - 5,92	3,34 2,93 - 3,99	6,67 6,02 - 8,03	5,59 4,08 - 6,99	2,23 1,62 - 2,73	6,15 5 - 7,29
SA	5,33 2,56-7,24	4,52 1,81 - 6,69	4,92 3,26 - 5,92	3,88 2,41 - 5,72	6,78 6,11 - 7,74	5,24 4,06 - 6,99	2,16 1,80 - 2,73	6 4,00 - 6,99
FA	5,34 3,70 - 6,30	6,1 4,60 - 6,96	4,88 4 - 5,99	3,4 1,72 - 4,88	7,13 6,05 - 8,03	4,92 3,57 - 6,44	2,54 1,62 - 2,96	5,61 4,26 - 7,15

Procedure for the word selection

A first survey was disseminated across the professional and personal networks of the research team members to identify addiction-related words. A first list of 90 addiction-related words was constituted for each BA and was presented for rating during the initial picture rating. Addiction-related words were rated and selected using the same procedure as with the pictures. A neutral, a positive and a negative word were paired with each addiction-related word. Neutral, positive, and negative words came from the FAN database (Monnier & Syssau, 2014; Syssau & Font, 2005) and Bonin's database (Bonin et al., 2003), although most of the words came from the FAN database. Indeed, Bonin's database was only used for longer words (which were especially present for SA) because the FAN database lacked such long words (9 to 13 thirteen letters and one word of 4 letters because a matching negative word was lacking). As no information about their arousal was available in Bonin's database and because valence was rated on a 5-point scale, the characteristics of these words were not included in the Additional Table 34. The same procedure used with the pictures was used for matching with the addiction-related words (see Additional Table 34 for numbers), except that words were also matched depending on their characteristics (number of letters, syllables, and phonemes).

Tableau 34 Arousal and valence of words stimuli - Supplementary data - Manuscrit 5

	Addiction stimuli		Neutral stimuli		Positive stimuli		Negative stimuli	
	Valence Mean <i>Min-Max</i>	Arousal Mean <i>Min-Max</i>	Valence Mean <i>Min-Max</i>	Arousal Mean <i>Min-Max</i>	Valence Mean <i>Min-Max</i>	Arousal Mean <i>Min-Max</i>	Valence Mean <i>Min-Max</i>	Arousal Mean <i>Min-Max</i>
GbD	5,02 3,5 - 7,13	5,01 2,42 - 7,58	4,94 4,35 - 5,46	2,85 2,3 - 3,4	7,53 6,84 - 8,43	5,74 4,32 - 7,86	2,30 1,36 - 3,32	5,66 4,24 - 7,44
GmD	5,67 4,33 - 7,75	4,94 3,98 - 6,25	5,02 4,38 - 5,81	3,22 2,47 - 3,9	7,52 6,03 - 8,58	5,67 4,04 - 7,5	2,68 1,35 - 3,59	5,48 7,16 - 4,19
SA	5,28	4,77	4,9	3,54	7,2	5,57	2,26	5,82

	2,88 – 7,66	2,5 – 6,71	4,08 – 5,62	2,47 – 3,92	6,13 – 8,58	4,04 – 7,5	1,35 – 3,65	4,28 – 7,44
FA	5,33	6,02	4,93	3,22	7,29	5,25	2,29	6,12
	1,6 – 7,25	4,04 – 7,4	4,08 – 5,59	2,35 – 3,89	6,13 – 8,43	4,04 – 7,19	1,36 – 3,43	4,47 – 7,44

S2: Apparatus of the study

Computerized cognitive tasks are programmed and presented using SuperLab Pro 5 (Cedrus Corporation, San Pedro, CA, USA). A PC desktop computer displays the tasks (64 bits, 3.50 GHz processor). The participants are seated with their eyes 60 cm from the computer. The SV-1 voice detection device (Cedrus Corporation) records vocal responses during the Stroop task. The participants use the 7-button response pad RB-730 (Cedrus Corporation) for go-nogo, stop signal, Stroop, visual dot probe, and single key impulsivity paradigm tasks.

During two tasks (Iowa gambling task and cue-reactivity task), various transducers record **psychophysiological responses**: A GSR amplifier (galvanic skin response) measures skin conductance levels using two sensors maintained by Velcro tape on the first phalanx of the forefinger and middle finger of the non-dominant hand (AdInstruments, Oxford, UK). A Trigno wireless ECG (electrocardiogram) sensor connected with two disposable electrodes, positioned in a bipolar configuration on the front of the two clavicles, measures inter-beat heart intervals (Delsys, Natick, MA, USA). A Trigno EMG (electromyogram) wireless system connected with miniature (25/12/7 mm) wireless surface EMG sensors positioned using specific adhesive skin interfaces measures the electrical activity of the *zygomaticus major* and the *corrugator supercilii* muscles (Delsys). Signals from the transducers are amplified and filtered using a 16-channel amplifier (PowerLab 16/35P, AdInstruments).

The StimTracker ST-100 (Cedrus Corporation) synchronizes the psychophysiological measurement system (Powerlab) and events from computerized cognitive tasks (SuperLab). Signals are digitalized at a 1000 Hz maximum sampling rate and then recorded, displayed, and analysed on a laboratory computer with LabChart 8 Pro software (AdInstruments).

S3: Details on the cognitive tasks

d²

Fourteen lines constitute the test. The participants have 20 seconds to process each line and find as many targets as possible. The number of items processed (GZ) reflects processing speed. The percentage of errors (the number of errors divided by the number of items processed) on the test expresses the accuracy of the participant's responses. Finally, subtracting the number of "good hits" minus errors of commission (distractors marked) provides the concentration performance component (KL). This score reflects the processing speed corrected by accuracy.

Stroop task

All words are displayed on the screen and written in upper-case letters. Each block is composed of a practice with eight trials followed by 24 trials. *In the first two conditions* (denomination and reading), each word/colour appears six times (4 different colours). *In the third condition* (interference), each word appears twice with the same incongruent colour. *In the emotional condition*, words appear by blocks of 8 words of the same valence to prevent carry-over effects (i.e., a speed reduction based on reaction time during the trial following a trial presenting emotional stimuli (Bar-Haim et al., 2007; Dresler et al., 2009; Hudson et al., 2013; Lorains et al., 2014; Robbins & Ehrman, 2005; Waters et al., 2003). For each valence, there are three blocks, with a pseudo-randomization that avoided two blocks of the same type following each other (8 words per block and four types of block displayed three times=24 words for each type and 96 trials in sum). Participant RTs are recorded with a voice detection device, while the experimenter presses colour buttons corresponding to the participant's response. This modality of response permits avoidance of the diminution of the interference effect inherent to the motor response modality (C. M. MacLeod, 1991; Penner et al., 2012).

Visual dot probe task (VDP)

The participants keep their fingers above the left and right button of the response box and look at a central fixation cross during the whole task. Six practice trials are presented at the beginning of the task and are composed of neutral pictures that are not used in the subsequent trials. Pairs of pictures (350 x 350 pixels) appear after 500 ms on both sides of the central fixation cross and remain on the screen for 250 ms. The fixation cross remains on the screen as well to prevent eye movements, based on Petrova, Wentura, and Bermeitinger's (2013) recommendation. Then, a target (a black dot) appears in the position of one of the pictures until the response of the participant or a 2000-ms maximum (see Additional Figure 10a). The participant has to press the left or right button of the response box, corresponding to the position of the target, as quickly as possible. This detection model was chosen instead of a discrimination model to assess low levels of detection and not higher cognitive processes that discrimination modality requires (van Rooijen et al., 2017). For each trial, one of the pictures is neutral, while the other is its matched picture and can be neutral, negative, positive, or addiction-related. There are twelve different pictures of each valence type (neutral, positive, negative, addiction-related) with four presentations of each: two times in a congruent trial (target is on the same side as the matched stimuli) and two times in a non-congruent trial (target is on the opposite side as the matched stimuli). The paired pictures are grouped by valence type and presented in blocks of 12 trials to avoid valence-related carry-over effects. The order of presentation is randomized inside the blocks. The order of block presentation is pseudo-randomized so as not present the same type of block twice in a row to avoid habituation, and the pseudo-randomization is counterbalanced to control for any effect linked to the order of testing. Sixteen blocks are thus presented (4 blocks of each type, 12 trials per block, 192 trials in sum) with four breaks allowing the patient to rest. The inter-trial interval fluctuates between 250, 500, or 750 ms. The computer records

(i) reaction time (RT), (ii) choice of the participant (left or right), (iii) type of trial (neutral-neutral, positive-neutral, negative-neutral, addiction related-neutral), and (iv) the congruence of the trial (if the target is on the same side of the cued picture or not). Subtracting mean RTs between congruent and non-congruent emotional trials gives the *attentional bias score*. A positive score highlights the presence of a bias towards the emotional stimuli, with faster reaction times when the probe is cued by the emotional stimuli. In contrast, a negative score highlights the presence of a bias away from the emotional stimuli (avoidance), with slower reaction times when the probe is cued by the emotional stimuli. When there is no imbalance between the allocation of attention, the value of the attentional bias score is zero (C. MacLeod et al., 1986). The presence of an attentional bias can be due either to an attraction towards the stimuli or to difficulty disengaging from it. Distinguishing attraction from difficulty to disengagement can be made by comparing neutral-neutral trials with emotional-neutral trials. In the case of an attraction towards emotional stimuli, the RTs should be faster in congruent emotional trials than in neutral trials. In the case of difficulties in disengaging attention of emotional stimuli, RTs should be slower in non-congruent emotional trials than neutral trials (Koster et al., 2004; van Rooijen et al., 2017).

Iowa gambling task (IGT)

Decks C and D include lower gains (+50 points) and frequent (deck C) or less frequent (deck D) low penalties (-250 points each 10 cards). These decks result in a global positive balance between gain and penalties and are thus considered advantageous decks. In contrast, decks A and B include higher gains (+100 points) but frequent (deck A) or rare (deck B) high penalties (including a loss of 1250 points each 10 cards). As a consequence, they result in a final net loss and are considered disadvantageous decks. The more profitable strategy is to privilege long-term rewards, i.e., the advantageous decks (Kovács et al., 2017). The participants have 2000€ of fictional money and are instructed to play as if it was their real money and to earn as much money as possible. They know neither which decks are advantageous nor when the task ends. At the end of the task, they are asked to judge which decks were advantageous and which were not (conceptual knowledge). The program records, for each trial, the RT, the deck chosen, and the money earned. Heart inter-beat intervals and electrodermal activity are also recorded 4 seconds before and 4 seconds after the decision (Goudriaan et al., 2006) to obtain data regarding physiological information provided by the autonomous nervous system in a situation of uncertainty.

Verbal fluencies

Outcomes are the number of correct responses and types of errors and the number of switches and clusters. Indeed, according to Troyer, Moscovitch, and Winocur (1997), quantitative analysis can be completed by qualitative analysis in which clustering corresponds to the grouping of words that come from the same semantic category (in the lexical modality) or with common phonemic properties (same two first letters for example) (in the phonological modality), while switching corresponds to going from one subcategory to another (Gierski & Ergis, 2004; Troyer et al., 1997).

Trail making test (TMT)

Outcomes on this task are time taken to complete both sheets and numbers and types of errors. The difference between the two conditions permits us to observe the cost of alternating, which represents the capacities of reactive flexibility.

M-CST (modified card sorting test)

During this task, the participants have to match the cards from the deck to the stimulus cards. They have to determine by themselves the correct matching rule from among three possible rules (number, colour, and shape), which are not told to the participant. After six consecutive correct answers, the category is considered completed, and the rule changes. After a first successful series of trials using consecutively the three possible rules (in the order decided by the participant), rules are repeated in the same order as previously, without the participant being aware. The number of cards used before for completing the six categories, the number of categories completed, the number of errors and perseverative errors (an error is perseverative when the answer uses the same rule as the previous trial while the experimenter qualified this previous answer as wrong) are recorded. We also added the “categorizing efficiency”: this score is obtained by multiplying the number of categories completed by the number of cards by categories; the number of cards not used is then added. This score permits us to capture more subtle cognitive alterations than the traditional M-CST performance parameters, as we expected our sample will not present with severe cognitive deficits (Cianchetti et al., 2005).

Tower of Hanoi

Points are attributed depending on the number of moves used and if the participant finishes before the time limit (from 30 to 240 seconds). The time before the first move and the total time of realization, the number of moves and errors, and the number of points are recorded. These different measures permit us to characterize performance between groups (number of points) but also to compare whether the pattern of realization is the same between groups (for example, time before the first move illustrates impulsivity in realization).

Go-nogo task

For each trial, a fixation cross stays on the screen for 500 ms. Then, a neutral or a related-addiction picture appears, with either a square (go trials) or a circle (nogo trials) at its centre (Additional Figure 10b; shapes are surrounded by black and white outlines to clearly distinguish them from the picture). The participants are instructed to press the button as fast as possible on go trials (squares) and to refrain from pressing on nogo trials (circles). Eighty percent of the stimuli indicated go trials (4 blocks of 60 trials: 48 go trials including 24 neutral pictures and 24 addiction-related pictures + 12 nogo trials with six neutral and six addiction-related pictures). Before the presentation of trials, a practice block using neutral stimuli not used during the test phase was conducted. This practice block includes 32 trials with 50% go trials and is used to habituate and stimulate the automatic association between stimuli and behaviour (Deleuze et al., 2017). The ITI after the presentation of the target varies between 500, 1000,

or 1500 ms to avoid the generation of an anticipated motor response because of a regular temporality of the press (Schulz et al., 2007). The number and types of errors, successes and RTs per type of stimuli are measured.

Single key impulsivity paradigm (SKIP)

The participants received the standardized instructions as proposed by Dougherty *et al.* (Dougherty et al., 2008) so that they know that the longer time that they wait between presses, the more points they would obtain. After each press, the cumulative number of points obtained appears at the top of the screen, and the number of points they obtained on the previous trial appears at the bottom of the screen. Regarding the attribution of points, the calculation is exponential and obtained with this formula (RT = time since the last press in seconds): $[RT + (3 \times RT^2)] / 100$. This formula is slightly different from the original task, with a division by 100 and not 1000, which allows a more rapid increase in points. The program records the mean duration between presses, the maximum wait between two presses, and the number of presses.

Stop Signal Task (SST)

For this emotional task (Logan & Cowan, 2014; Lorains et al., 2014), each trial begins with a fixation cross that remains on the screen for 500 ms. Then, a picture is displayed in the centre of the screen (350 x 350 pixels), with an arrow at its centre (the direction can be either right or left, black and white outlines surround arrows to distinguish them from the picture). Those pictures can be either neutral or related to addiction (12 pictures for each). On 25% of the trials, a STOP signal is emitted as a sound for 1 second (5 blocks of 64 trials = 320 trials in sum, 64 STOP trials). The pictures stay on the screen for 1500 ms, and ITI is 1000 ms (see Additional Figure 10c).

Subjects must fixate on the fixation cross and press the button corresponding to the direction of the arrow on the screen. Arrows were chosen instead of crosses and circles to avoid the difficulty of memorizing the association with the correct response (Grant et al., 2012; Odlaug et al., 2011). When the STOP signal occurs, they have to refrain from pressing the button and wait for the next trial. The participants are advised that trial difficulty increases because the software adapts itself to their performance. Actually, the stop-signal delay (SSD; delay between the appearance of the picture and the STOP signal in STOP trials) varies between 0 and 1500 ms according to the staircase algorithm (Verbruggen & Logan, 2008). Indeed, for each correct response to a STOP trial, the SSD increases by 25 ms, while for each wrong response, it decreases by 25 ms. The experiment begins with a practice of 32 trials (8 STOP and 24 GO with neutral pictures), without the alterations in delay that depend on responses. At the end of each block, a break is offered, and feedback (number of correct responses) appears on the screen. The SSRT (stop signal reaction time) is then calculated with the integration method by blocks to avoid bias in the calculation of the SSRT in case of strategic slowing of responses as the task progresses (Verbruggen et al., 2013). To compensate for missing values, omissions (non-

response to GO trials) were replaced by maximum RT obtained during GO trials (Verbruggen et al., 2019).

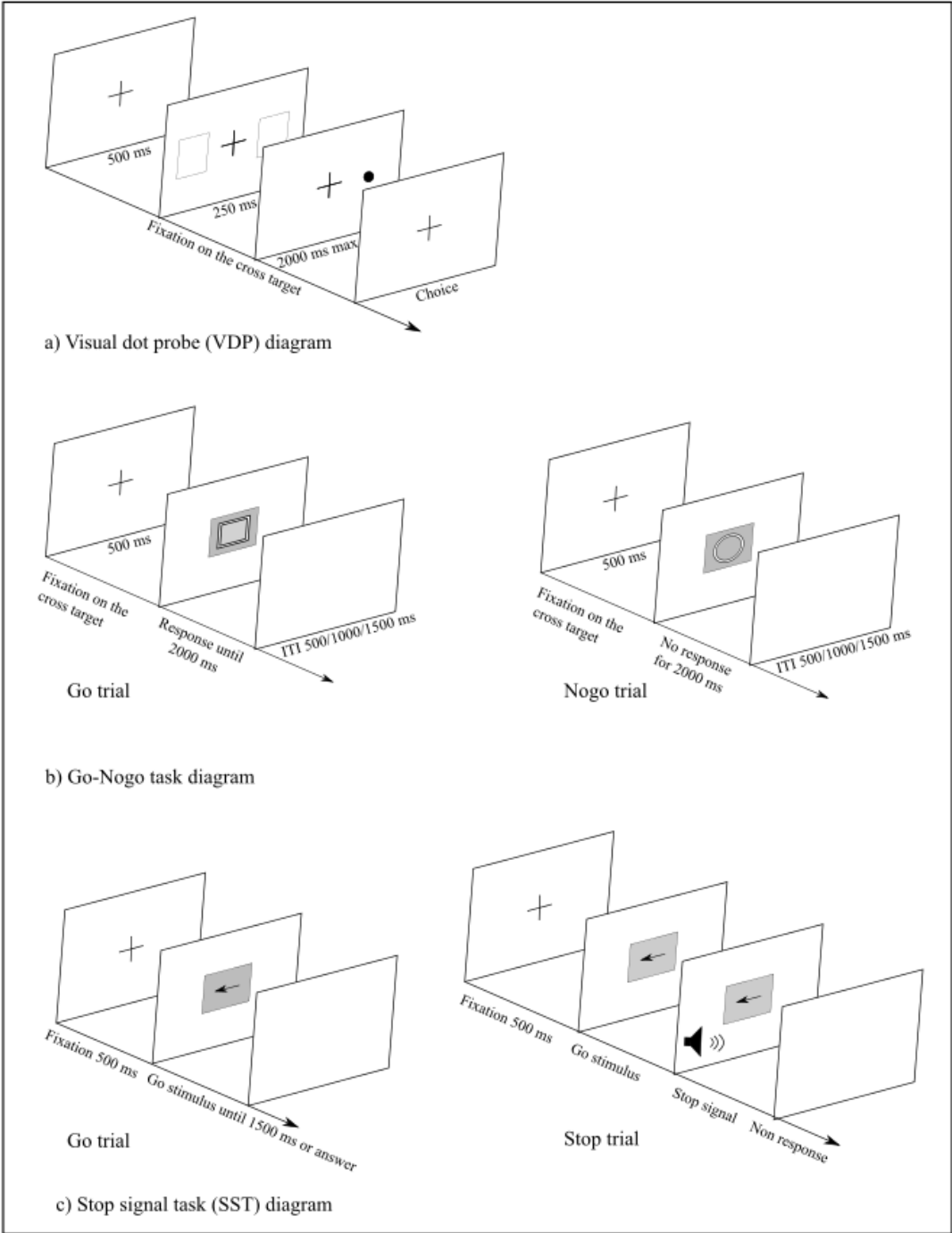


Figure 10 Diagram of computerized tasks

Annexe 5 : Données supplémentaires issues des analyses préliminaires de l'étude BANCO ; effet du niveau d'intelligence prémorbide

Tableau 35 Données supplémentaires - Analyses préliminaires de l'étude BANCO - Effet du niveau d'intelligence prémorbide

	JHA	Contrôles	p value de la comparaison de groupes
Moyenne (sd) du score de fNART [min – max]	23.82 (5.81) [13 – 30]	24.64 (3.32) [20 – 30]	0.52
Corrélation avec les scores aux tâches cognitives d'évaluation de la CS			
	Rho	P value	
Faux-pas			
Score histoires faux-pas (/30)	0,06	0,81	
<i>Question d'identification faux-pas et non faux-pas (/15)</i>	0,06	0,80	
<i>Question d'identification du personnage fautif (/5)</i>	0,26	0,24	
<i>Question d'explication (/5)</i>	0,21	0,34	
<i>Question de justification (/5)</i>	0,14	0,54	
<i>Question d'intentionnalité (/5)</i>	-0,09	0,68	
<i>Question d'émotion ressentie (/5)</i>	0,12	0,61	
Score histoires non faux-pas (/10)	-0,16	0,49	
Score total (/40)	0,03	0,88	
Score questions contrôles (/20)	0,06	0,81	
Reconnaissance des émotions faciales			
Total (/35)	0,19	0,39	
<i>Joie</i>	0,36	0,10	
<i>Peur</i>	-0,09	0,68	
<i>Dégoût</i>	0,05	0,83	
<i>Colère</i>	0,23	0,31	
<i>Surprise</i>	0,26	0,24	
<i>Tristesse</i>	0,03	0,89	
<i>Neutre</i>	-0,11	0,63	
Métacognition sociale (scores moyens non normalisés)			
<i>Avant la tâche de faux-pas</i>	0,35	0,11	

Annexe 4 : Données supplémentaires – Analyses préliminaires BANCO

<i>Après la tâche de faux-pas</i>	0,30	0,17
<i>Avant la tâche de reconnaissance des émotions faciales</i>	-0,41	0,06
<i>Après la tâche de reconnaissance des émotions faciales</i>	-0,21	0,34
