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PAR
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TRAITER LA DÉPENDANCE À LA NICOTINE PAR LE NEUROFEEDBACK CHEZ LES ADULTES AYANT UN TROUBLE DÉFICITAIRE DE L'ATTENTION

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Cette thèse est rédigée en anglais tel qu'il est permis dans les règlements des études de cycles supérieurs de l'Université de Sherbrooke. Dans ce cas, l'article 5.3 du règlement mentionne l'obligation de présenter un exposé substantiel rédigé en langue française dans lequel sont présentés les objectifs, la méthodologie et les résultats obtenus.

Composition du jury

Traiter la dépendance à la nicotine
par le neurofeedback chez les adultes
ayant un trouble déficitaire de l'attention

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Ce mémoire a été évalué par un jury composé des personnes suivantes :

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Sommaire

Le trouble déficitaire de l'attention avec hyperactivité (TDAH) et le tabagisme ont un lien établi. Les personnes atteintes d'un TDAH sont plus portées à développer une dépendance à la cigarette, à débuter le tabagisme plus jeune et ont plus de difficultés à cesser de fumer. Il est maintenant connu que le traitement du TDAH modifie ces interactions. Bien que les psychostimulants soient le traitement pharmacologique de choix pour le TDAH, les effets secondaires indésirables de ces substances réduisent considérablement l'utilisation par ceux qui veulent cesser de fumer, surtout s'ils utilisent déjà des substances ayant des propriétés stimulantes, tel que la nicotine, pour les aider. Cette étude a comme objectif d'évaluer l'efficacité potentielle d'un traitement de neurofeedback chez des adultes atteints d'un TDAH et qui, malgré l'utilisation d'un timbre de nicotine, n'arrivaient toujours pas à cesser de fumer. Quatre participantes qui ont rencontré les critères de recherche pour le TDAH ont reçu 12 à 14 séances de neurofeedback pendant qu'elles continuaient un traitement avec un timbre de nicotine. L'efficacité de l'intervention en neurofeedback est évaluée selon un devis de recherche à cas unique avec lignes de base multiples établies en fonction des participants. L'analyse post-intervention révèle que trois des quatre participantes ont réduit de façon significative leur dépendance sur la nicotine à la suite du traitement. Le neurofeedback déjà connu comme traitement efficace du TDAH, dans le cas de dépendance à la nicotine, peut améliorer la tolérance aux symptômes de sevrage en passant par une amélioration de l'attention.

MOTS-CLÉS : Trouble déficitaire de l'attention avec hyperactivité (TDAH), neurofeedback, sevrage, nicotine

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Dédié à Zoe, Malcolm et Gordon

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Résumé

Le contexte de l'étude

Le trouble déficitaire de l'attention avec hyperactivité (TDAH) et le tabagisme figurent parmi les problèmes psychiatriques et comportementaux les plus courants et les plus coûteux auxquels la société doit faire face de nos jours. Plus de 37 000 Canadiens sont décédés prématurément à cause du tabagisme en 2007 et il est prouvé que le tabagisme est relié à plus de deux douzaines de maladies et de conditions physiques problématiques (Santé Canada, 2007). Le TDAH est un trouble neurodéveloppemental impliquant des problèmes d'attention, d'hyperactivité et d'impulsivité (APA, 2000). Dans le monde, on estime à 5,3 % la proportion des enfants et des adolescents atteints du TDAH (Polanczk, Silva de Lima, Horta, Biederman & Rohde, 2007) et 4 à 4,5 % des adultes (Kessleer, Chiu, Demler, & Walter, 2005). Le TDAH a été longtemps considéré comme un trouble lié à l'enfance, mais il est désormais admis que 40 à 60 % des enfants diagnostiqués continuent de répondre aux critères diagnostiques à l'âge adulte (Barkley, Fischer, Smallish, & Fletcher, 2002; Biederman, Petty, Evans, Small, & Faraone, 2010; Kessler et al., 2010).

Les adultes et les adolescents atteints du TDAH sont plus susceptibles de commencer à fumer à un plus bas âge et de progresser plus jeune vers un usage régulier de la cigarette (Breyer, Burgetova, & Roper, 2009; Galéra, Fombonne, Chastang, & Bouvard, 2004; Molina & Pelham, 2003). Ils fument beaucoup plus que la population en général et il y a un lien direct entre les symptômes du TDAH et le nombre de cigarettes fumées (Pomerleau, Downey, Stelson, & Pomerleau, 1995). Les symptômes de sevrage chez cette population clinique sont plus importants (Knott et al., 2008), ils recommencent à fumer plus rapidement (Humfleet et al., 2005) et un plus petit nombre d'entre eux, en particulier les hommes, cessent de fumer définitivement (McClernon & Kollins, 2008). Bien que pour les troubles liés à l'utilisation de certaines substances, le TDAH

en tant que facteur de risque peut être attribuable presque complètement à la présence d'autres comorbidités, dans le cas de la consommation de nicotine, le TDAH semble être un facteur de risque direct (Biederman et al., 2006a; Breyer et al., 2009; Pomerleau et al., 2003; Wilens et al., 2008).

Aujourd'hui, la plupart des chercheurs croient qu'un traitement pharmacologique précoce du TDAH peut modifier ces interactions et améliorer les résultats de la désaccoutumance au tabac (Wilens et al., 2008), mais les conclusions de plusieurs études importantes ne soutiennent pas ce constat. Cela est particulièrement notable dans le rapport du MTA (*the NIMH Collaborative Multisite Multimodal Treatment Study of Children with ADHD; 2009*), qui révèle qu'un traitement aux stimulants administré tôt n'a pas procuré d'avantage à long terme dans l'utilisation de la cigarette chez des patients comparativement à un groupe témoin non médicamenté (Molina et al., 2009). De plus, une préoccupation demeure concernant ces traitements médicamenteux qui, selon certaines études en laboratoire, pourraient même accroître le risque du tabagisme (Silverstone & Dardashova, 2012). Néanmoins, le consensus actuel semble soutenir le constat que le traitement pharmacologique dans l'enfance dans le cas du TDAH ne contribue pas aux abus de substance éventuels (incluant la cigarette), mais qu'il n'en protège pas non plus.

Cependant, des traitements combinés utilisant des médicaments pour le TDAH et un timbre de nicotine pour la cessation tabagique ont obtenu un certain succès, bien que les résultats aient été limités, étant donné l'impact de certains facteurs tels que les effets secondaires et la composition de l'échantillon (Covey, Manubay, Jiang, Nortick, & Palumbo, 2008; Winhusen et al., 2010). En tant que tel, un traitement alternatif contre le TDAH combiné à un traitement pour cesser de fumer sans contribuer à des effets secondaires potentiels serait utile.

Le neurofeedback est un traitement non pharmacologique alternatif du TDAH, qui vise la régulation de l'activité électrique du cerveau. Grâce à de nombreuses études menées entre 2006 et 2009, il est de plus en plus reconnu comme une approche efficace contre les symptômes du TDAH. Une métaanalyse récente effectuée par Arns, de Ridder, Strehl, Breteler et Coenen's (2009) indique les valeurs moyennes de l'ampleur de l'effet, dont *1,02* pour l'inattention, *0,71* pour l'hyperactivité et *0,94* pour l'impulsivité. Les importants coûts individuels, sociaux et des soins de santé reliés à la comorbidité entre le tabagisme et les troubles de l'attention justifient le nombre croissant de projets de recherche ayant pour but d'élucider l'impact de différents traitements du TDAH sur le tabagisme.

Les fondements théoriques de l'étude

Bien que le lien entre le TDAH et le tabagisme soit désormais reconnu, il reste maintenant à déterminer la nature de ce lien, ce qui n'a pas été évident étant donné non seulement la nature imprécise du diagnostic chez l'adulte, mais également à cause de la présence de comorbidités importantes qui brouillait les conclusions des écrits (Gray & Uphadhyaya, 2009). De plus amples recherches s'avèrent nécessaires afin de trouver une réponse complète, mais il y a néanmoins suffisamment d`indices dans les écrits pour établir qu'il y a un lien neurobiologique particulier entre l'aspect d'inattention du TDAH et la dépendance à l'usage du tabac. (Burke, Loeber, White, Stouthamer-Loeber, & Pardini, 2007; Lerman et al., 2001; Tercyak, Lerman, & Andrain, 2002).

Le TDAH et ses « présentations »

Les critères pour un diagnostic de TDAH ont été modifiés avec la 5e édition du *Diagnostic and statistical manual of mental disorders* publié en mai 2013 par l'*American Psychiatric Association* (DSM-V). La présente étude, ainsi que la majorité des études citées dans ce texte, a utilisé les critères du DSM-IV-TR, donc il serait utile de réviser les derniers changements

(American Psychiatric Association, 2000). Le TDAH se trouve maintenant dans la catégorie des troubles neurodeveloppementaux, ce qui souligne que le TDAH peut être présent aux différentes étapes de la vie, mais avec des manifestations particulières dépendamment de l'âge. Il y a maintenant trois présentations au lieu de trois sous-types : inattention prédominante ; hyperactivité/impulsivité prédominante ; et mixte. Le nombre de symptômes qui doivent être identifiés pour un diagnostic chez l'enfant n'a pas changé (toujours six pour chaque présentation) mais pour l'adolescent (17 ans et plus) et l'adulte, le nombre est maintenant établi à cinq. Les comportements problématiques doivent produire des effets négatifs sur le fonctionnement ou le développement dans au moins deux milieux de vie de la personne et être à un degré qui ne correspond pas au niveau de développement approprié à l'âge de la personne (c.-à-d. être plus fréquent et plus sévère que ce qu'on observe chez des personnes d'un niveau de développement similaire). Les symptômes doivent maintenant être présents avant l'âge de 12 ans, alors qu'antérieurement le DSM-IV exigeait l'apparition de symptômes avant l'âge de 7 ans. Quelques exemples des symptômes d'inattention sont : ne parvient pas à prêter attention aux détails; fait des fautes d'inattention; a du mal à soutenir son attention; semble souvent ne pas écouter; ne se conforme pas aux consignes; a souvent du mal à s'organiser. Pour la présentation de la prédominance hyperactivité/impulsivité, les symptômes sont par exemple : a du mal à se tenir tranquille ; parle trop ; a souvent du mal à attendre son tour ; interrompt souvent les autres ; démontre une agitation excessive. Il y a plusieurs controverses par rapport à l'établissement du diagnostic du TDAH. Bien que certains déficits cognitifs (attention et fonctions exécutives) soient souvent identifiés comme étant associés au TDAH, certains auteurs estiment que des tests neuropsychologiques ne sont pas nécessaires à l'évaluation diagnostique (Haavik, Halmoy, Lundervold, & Fasmer, 2010). Ces tests facilitent surtout l'identification des accommodements qui peuvent être utiles pour le bon fonctionnement de l'individu.

L'hétérogénéité des profils cognitifs et comportementaux associés au diagnostic du TDAH, en plus du manque de consensus sur la façon de diagnostiquer le trouble, surtout chez les adultes, et plus particulièrement dans le contexte de recherches sur les comorbidités (tels que les abus de substances) fait qu'il est difficile de déceler sans équivoque le lien entre la cigarette et le TDAH en utilisant les écrits scientifiques actuels. Néanmoins, ce qui ressort de cette quantité de recherche semble suggérer que l'inattention joue un rôle unique dans le développement du tabagisme chez les personnes avec le diagnostic.

Le rôle des sous-types du TDAH et le degré de sévérité

Plusieurs études ont établi que les risques pour le tabagisme peuvent être associés à chaque dimension du trouble, mais de façons divergentes (Burke, Loeber,White, Stouthamer-Loeber, & Pardini, 2007). Selon une revue attentive des écrits effectuée par Looby (2008), il apparaît clairement que l'hyperactivité/impulsivité n'est pas invariablement reliée à l'usage précoce du tabac. Elle est plus souvent considérée comme contribuant à mener avec le temps à une forte consommation de tabac et serait également reliée à la présence du trouble de la conduite ou à d'autres facteurs psychosociaux (comme l'usage du tabac dans la famille). L'impulsivité aurait toutefois un effet direct sur la capacité à cesser de fumer une fois la cigarette est devenue une habitude (Covey, Manubay, Jiang, Nortick, & Palumbo, 2008). Par contre, l'inattention semblerait être particulièrement associée au risque de développer une dépendance à la nicotine (Lerman et al., 2001).

Ce lien est tellement important que le degré de sévérité associé aux difficultés d'inattention est souvent corrélé avec le nombre de cigarettes fumées et la dépendance à la nicotine, que ce soit dans une cohorte avec un diagnostic ou pas (Fuemeller, Kollins & McClernon, 2007; Lerman, 2001). Certains auteurs suggèrent que même sans diagnostic formel, la présence de symptômes d'inattention importante pourrait augmenter le risque du tabagisme et que ces personnes méritent

alors d'être ciblées pour un traitement. Chez *65 %* des garçons et *33.3 %* des filles diagnostiqués dans l'enfance, les symptômes du TDAH diminuent suffisamment pour que le diagnostic s'estompe. Mais des difficultés reliées au diagnostic, tel que le tabagisme, peuvent persister à un point tel que le bien-être de la personne reste hypothéqué. Dans une étude qui examinait les difficultés adultes de ces enfants une dizaine d'années plus tard, *38 %* des garçons et *11 %* des filles fumaient. En comparaison, *15 %* du groupe de contrôle masculin non diagnostiqué dans l'enfance et *4 %* des filles sans diagnostic utilisaient la cigarette. En conclusion, l'inattention joue un rôle significatif par rapport à la dépendance à la nicotine, mais est-ce que l'impact de ce facteur est direct ou passe par une comorbidité quelconque? Bien entendu, la dépendance à la nicotine n'est pas la seule comorbidité qui jumelle le TDAH. Dans la mesure de comprendre l'interaction entre l'inattention et l'utilisation de la cigarette, il faut d'abord se pencher sur les recherches examinant l'usage d'autres substances et d'autres problèmes de santé mentale.

Le TDAH, le tabagisme et les troubles liés à l'utilisation des substances (TUS)

Il y a eu un consensus voulant que les individus atteints du TDAH ont un risque accru de développer des troubles liés à l'utilisation de nombreuses substances incluant l'alcool, la marijuana, la cocaïne, les méthamphétamines et la cigarette, mais les premières études traitant du TDAH et des TUS ne distinguaient pas le tabagisme de la consommation d'autres substances (Biederman, Wilens, Wick, Faraone, & Spencer, 1998). Le tabac a souvent été étudié conjointement avec d'autres substances, possiblement à cause de son omniprésence et de l'usage répandu de la cigarette chez les personnes ayant reçu un diagnostic de maladie mentale. En effet, dans un échantillon de patients ayant des troubles liés à l'utilisation de substances, presque tous les sujets (98,6 %) fumaient (Abrantes, Brown, & Tomlinson, 2003). Alors, quand on expliquait le risque élevé par la présence de comorbidités particulières, on tenait également pour acquis que le lien du TDAH et la cigarette s'expliquait de la même façon. Par exemple, le TDAH en tant que

facteur de risque pour la consommation subséquente de cocaïne peut être attribuable presque entièrement à la présence du trouble de la conduite (Barkley, Fischer, Smallish, & Fletcher, 2004).

Lorsque le tabagisme est étudié indépendamment des autres substances, les résultats ne sont pas les mêmes. Comme pour les troubles liés à l'utilisation d'alcool ou de cocaïne, les chercheurs ont examiné le rôle de comorbidités telles que le trouble de la conduite, le trouble oppositionnel et d'autres états psychiatriques en lien avec l'usage du tabac, croyant qu'il y avait également un lien indirect entre le risque du tabagisme et le TDAH (Galera, Fombonne, Chastang, & Bouvard, 2005). Deux études majeures contrôlant pour la psychopathologie mentionnent que de tous les TUS considérés, seul le risque de dépendance à la nicotine à vie est supérieur chez ces personnes (Biederman et al., 2006b; Molina & Pelham, 2003).

Des études récentes en neurogénétique ont démontré que les systèmes cholinergiques peuvent également être modifiés chez les personnes atteintes du TDAH, ce qui explique partiellement le lien entre la cigarette et le TDAH (Potter, Newhouse, & Bucci, 2006). Une hypothèse soutient que les mécanismes sous-jacents au TDAH et les effets physiologiques de la nicotine partagent un système commun de neurotransmetteurs (Wilens et al., 2008). Ces faits ont provoqué plusieurs projets de recherche sur les effets de la médication utilisée pour améliorer les symptômes du TDAH comme traitement pour la cessation du tabagisme.

Les psychostimulants constituent le traitement privilégié pour le TDAH. Une étude sur l'usage du méthylphénidate pompe osmotique élémentaire pour la voie orale (MPH OROS), conjointement avec des substituts à la nicotine, a conclu qu'il y avait un impact, mais mitigé, sur les résultats de désaccoutumance au tabac chez les adultes atteints du TDAH (Winhusen et al., 2010). Les participants de cette étude ont réussi à diminuer minimalement le nombre de cigarettes quotidiennes, mais la cessation du tabagisme n'était pas suffisamment élevée pour être

significative. Bien que cette étude rapporte une réduction significative des symptômes du TDAH dans le groupe MPH OROS, elle note également un taux supérieur d'effets secondaires indésirables (tels que la dyspepsie, le rythme cardiaque élevé, l'hyperactivité accrue, des palpitations) causés par le traitement combiné. Ces désagréments peuvent avoir contribué aux symptômes de sevrage, déjà difficiles, vécus par les participants et peuvent avoir éclipsé tout avantage relié à l'amélioration des symptômes du TDAH, relativement au groupe non médicamenté atteint du TDAH. Une alternative thérapeutique causant peu ou pas d'effets secondaires lorsqu'administré adéquatement serait alors potentiellement bénéfique pour les adultes avec un TDAH qui veulent cesser de fumer.

Le neurofeedback, l'attention et le TUS

Le neurofeedback, aussi connu sous le nom de rétroaction biologique électroencéphalographique (EEG), est un traitement alternatif non invasif pour plusieurs états, mais a jusqu'à maintenant servi principalement à traiter les crises épileptiques et le TDAH, pour lesquels il est reconnu comme un traitement efficace et fondé sur des données probantes (Yucha & Montgomery, 2008; Sherlin, Arns, Lubar, & Sokhadze, 2010). Le neurofeedback, qui a réellement débuté dans les années 1960 et 1970, est une forme de rétroaction biologique utilisant des capteurs sur la tête d'un individu afin de lui procurer l'information en temps réel sur ses ondes cérébrales. L'entraînement par le neurofeedback est une technique de conditionnement opérant visant à renforcer ou à inhiber des ondes cérébrales particulières. L'activité EEG se divise en différentes bandes de fréquences. Les ondes de moins de 4 Hz sont les ondes delta (ondes lentes correspondant à l'état de sommeil) ; les fréquences de 4 à 8 Hz correspondent aux ondes thêta (état somnolent, inattentif) ; les fréquences de 8 à 12 Hz correspondent aux ondes alpha (état de détente, éveil) ; enfin, les ondes de 12 à 30 Hz sont les ondes bêta (état actif, attentif). Le schéma

électroencéphalographique le plus courant identifié chez les enfants atteints du TDAH correspond à des ondes excessivement lentes dans les régions frontales du cerveau (Chabot & Serfontein, 1996; Thompson & Thompson, 2003). Chez les adolescents et les adultes, l'état le plus associé avec l'inattention, vécue comme «l'esprit brouillon» a été nommé « thalpha » car il correspond à de basses fréquences allant de 6 à 10 Hz, ce qui englobe les ondes cérébrales thêta et alpha (Thompson & Thompson, 2003). Une étude récente comparant 34 adultes atteints du TDAH avec 34 sujets témoins présente des résultats semblables à l'étude de Chabot et Serfontein (1996). Les patients atteints du TDAH ont démontré une densité de puissance absolue dans les bandes alpha et thêta significativement plus élevée que la norme (Koehler et al., 2002), une meilleure analyse statistique (Rossiter, 2004b) et des mesures plus précises grâce à l'imagerie par résonnance magnétique fonctionnelle (Levesque, Beauregard, & Mensour, 2006). Néanmoins, l'une des principales critiques sur la recherche dans ce domaine est le manque d'études cliniques randomisées (Loo & Barkley, 2005). Dans une étude rigoureuse publiée récemment dans le *Journal of Child Psychology and Psychiatry*, cette critique a été abordée (Gevensleben et al., 2009).

Le neurofeedback a également servi à traiter les TUS depuis les années 1990. Le principal type d'entraînement dans ce domaine a été le protocole de rétroaction des ondes cérébrales alpha-thêta, développé par Peniston et Kulkosky (1989) pour le traitement de l'alcoolisme (Trudeau, 2005). Bien que de nombreuses études aient reproduit les résultats appuyant l'efficacité du protocole alpha-thêta en tant que cothérapie pour aider les alcooliques chroniques résistants au traitement, son efficacité à traiter les troubles liés à d'autres substances telles que la cocaïne, la marijuana et les stimulants s'est avérée moins concluante. Ce traitement a ensuite été modifié afin d'inclure un protocole additionnel souvent employé pour les problèmes d'attention. Cette adaptation du traitement a été nommée la modification Scott-Kaiser au Protocole Peniston (Scott, Kaiser,

Othmer, & Sideroff, 2005). Elle impliquait l'entraînement de sujets provenant d'une population hétérogène souffrant d'abus de substances à l'aide d'un protocole SMR-bêta, jusqu'à ce que leurs résultats d'attention à un test de performance continu soient normalisés, avant d'entamer le protocole alpha-thêta. Dans un essai clinique randomisé sur le protocole modifié, 77 % des participants du groupe expérimental étaient abstinents après 12 mois, comparativement à 44 % pour le groupe témoin.

En conclusion, bien que le neurofeedback ait déjà été utilisé avec succès pour les problèmes d'attention dans le contexte de différents TUS, il n'y a pas de recherches sur le neurofeedback dans un contexte de désaccoutumance au tabac chez les adultes atteints du TDAH.

Les objectifs

L'objectif principal de cette étude consiste à évaluer l'effet du neurofeedback dans le contexte d'un traitement conventionnel de désaccoutumance au tabac chez les adultes souffrant à la fois du TDAH et de la dépendance à la nicotine. L'étude visera plus particulièrement à évaluer l'effet d'un protocole de traitement SMR-bêta sur la capacité des adultes atteints du TDAH de s'abstenir de fumer, en améliorant l'attention, dans le cadre d'un traitement de désaccoutumance au tabac sous forme de timbres à la nicotine.

Hypothèse

L'intervention en neurofeedback servira à réduire de façon significative la dépendance à la cigarette telle que mesurée par une échelle évaluant la dépendance à la nicotine telle que définie par le DSM-IV-TR et sans aggraver les symptômes de sevrage, tels que mesurés par une échelle évaluant six dimensions du syndrome de sevrage, chez des fumeurs atteints du TDAH qui ne réussissent pas à abandonner le tabac malgré une thérapie de remplacement de la nicotine.

Méthode

Un protocole expérimental à cas unique a été utilisé pour évaluer les effets de l'intervention en neurofeedback (Kazdin, 1978). Afin de maximiser la validité interne de la recherche, des niveaux de base multiples en fonction des participants ont été utilisés dans ce devis (Kratochville & Levin, 2010). Le traitement en neurofeedback était donc introduit à différents moments pour chaque participant afin de réduire les effets possibles de facteurs externes sur les résultats. La période de la première phase pendant laquelle le participant poursuivait son traitement avec la nicotine était entre une et trois semaines, permettant ainsi une stabilité du point de vue des mesures de base quotidiennes avant l'introduction de l'intervention.

Déroulement

Le recrutement s'est fait parmi les patients de cliniques dans la région de l'ouest de l'île de Montréal et visait les personnes qui consultaient pour la cessation tabagique. Les participants potentiels ont été contactés par téléphone par la chercheure au fur et à mesure qu'ils se présentaient entre le printemps et l'automne de 2012. Les objectifs de l'étude ainsi que la nature de l'implication recherchée leur ont été brièvement expliqués et l'ASRS v1.1 ainsi que le FTND ont été administrés. Au premier rendez-vous le diagnostic du trouble attentionnel a été clarifié au moyen de la trousse d'évaluation du TDAH de CADDRA (The Canadian Attention Deficit Hyperactivity Disorder Resource Alliance); l'Échelle d'évaluation de Wender Utah et un test de performance continue (IVA+ Plus). Sept personnes ont été recrutées initialement. Six femmes qui satisfaisaient les critères d'inclusion ont été retenues pour cette étude et ont signé un formulaire de consentement une fois les renseignements énumérés concernant le traitement, dont les risques et bénéfices potentiels. Deux participantes n'ont pas pu prévoir de disponibilités pour l'étude et se sont désistées. Quatre femmes se sont présentées à un rendez-vous additionnel pour

un éléctroencéphalogramme quantitatif (qEEG). Par la suite, les quatre participantes (VB, CR, JW, MT) ont été assignées à des niveaux de base préétablis, mais de façon non concurrente, car deux participantes ont débuté au mois de septembre (CR et JW), une au mois d'octobre (VB), et une à la fin décembre. (Des contretemps pour deux des participantes (VB et MT) ont nécessité la modification de la durée de deux niveaux de base.) La durée actuelle de la phase initiale sans traitement, avec des mesures quotidiennes de chaque variable dépendante, était sept jours pour la participante MT; huit jours pour JW; dix jours pour CR; et vingt jours pour VB. Le traitement a été initié les jours huit, neuf, onze et vingt et-un, et les mesures quotidiennes ont été maintenues pendant la phase intervention. Cette phase terminait quand un test de performance hebdomadaire continu indiquait une amélioration de l'attention. L'amélioration de l'attention objectivée par l'IVA+Plus constituait une condition d'arrêt du traitement, tout comme dans l`étude de Scott et al. (2005). Comme l'objectif ultime d'une intervention de cessation tabagique est l'arrêt complet de l'utilisation des cigarettes, l'évaluation de l'abstinence des participantes, utilisant la mesure de dépendance initiale, a été reprise dix semaines après la fin de la phase d'intervention. .

Instruments de dépistage

FTND : Test de dépendance à la nicotine de Fagerström. Le FTND (voir Appendice2) mesure quantitativement la dépendance en six questions notées sur dix points **(**Heatherton, Kozlowski, Frecker, & Fagerstom, 1991). Le FTND est le test le plus connu et le plus utilisé par les chercheurs. Le coefficient de consistance interne (alpha de Cronbach) est 0,68 pour le FTND. Comme mesure de dépistage, le score FTND est suggéré par plusieurs auteurs pour identifier un fumeur avec une dépendance forte se situant à un score de plus de ≥ cinq (Huang, Lin & Wang, 2005). L'échelle a été validée en français (Etter, Duc, & Perneger, 1999).

ASRS v1.1 : L'échelle d'auto-évaluation des troubles déficitaires de l'attention avec hyperactivité de l'adulte (Organisation mondiale de la santé). Ce questionnaire de 18 items a été

conçu comme outil de dépistage pour les professionnels de la santé (voir Appendice 3). Il est basé sur les symptômes du TDAH adulte tels que rapportés dans le DSM-IV-TR (APA, 2000). La première partie du questionnaire constitue l'ASRS-6, un outil avec une fidélité test-retest de *0,58 à 0,77*, et un coefficient de consistance interne *de 0,63 à 0,72* (Kessler et al., 2007).

IVA+Plus : Integrated Visual and Auditory Continuous Performance Test Plus. Ce test de performance continu (CPT) a fait partie de l'évaluation initiale de l'attention et a servi également comme mesure hebdomadaire pendant les deux phases de l'étude **(**Sandford & Turner, 2000)**.** Le IVA+Plus est une épreuve cognitive, réalisée sur ordinateur, qui se distingue de la majorité des tests continus de performance, par le fait qu'il comprend des mesures en modalité auditive et visuelle intégrées (voir Appendice 5 pour un exemplaire du rapport). L'indice global pour l'attention (Full Scale Attention Quotient) mesure l'attention et les erreurs d'omission et démontre une fidélité test-retest de *0,66 à 0,75* (Seckler, Burns, Montgomery, & Sandford (1995). Le deuxième indice global mesure le temps de réaction et les erreurs de commission (Auditory and Visual Response Response Quotient) avec une fidélité test-retest de *0,37 à 0,41*. Le IVA+Plus a été évalué pour la validité et la fidélité test-retest (intervalle de quatre semaines) auprès d'un échantillon de référence de personnes âgées de 6 à 70 ans. Il a également été utilisé comme mesure pour diverses populations cliniques infantiles (Tinius, 2003) et adultes (Corbett & Constantine, 2006; Quinn, 2003).

Instruments de mesure

CDS-12 et CDS-5 : Cigarette Dependence Scale. Le test CDS-12 devait être la mesure primaire de l'étude et a été complété quotidiennement tout au long de l'étude (Etter, 2005). Il a été choisi en partie parce qu'il fut développé à l'origine en français, puis traduit et validé en anglais. Le CDS-12 (voir Appendice 7) comprend 12 items qui mesurent différents aspects de la dépendance à la cigarette selon les critères du DSM-IV-TR (American Psychiatric Association,

2000) et de la Classification internationale des maladies CIM-10 (World Health Organisation, 1992). Au moment d'analyser les données, la variabilité des scores du CDS-12 était trop importante pour bien interpréter les résultats. Le CDS-5, un instrument composé des 5 premières questions du CDS-12 et validé également comme mesure de la dépendance à la nicotine, a été substitué pour le CDS-12. La recherche démontre que ces deux instruments sont plus sensibles aux changements que la majorité des échelles évaluant la dépendance tabagique (Le Houezec, 2010). Pour le CDS-12, un score jusqu'à 25 points indique une dépendance modérée, entre 25 et 44 points une dépendance moyenne et $\geq$45 une forte dépendance. Le score moyen de 3009 fumeurs a été établi à 44 points. Le CDS-12 possède de bonnes propriétés psychométriques avec un alpha de Cronbach de *0,84* et un test-retest de *0,83*. Pour le CDS-5, les scores sont de 5 (faible dépendance) à 25 (forte dépendance). Le CDS-5 comme instrument de mesure de la dépendance à la nicotine a également été validé et la corrélation avec les niveaux de cotinine sanguine est légèrement plus grande que celle du CDS-12 (Sato, Sato, Nozawa, & Sugimura, 2012).

CWS-21 : Cigarette Withdrawal Scale. L'évaluation quotidienne des symptômes de sevrage s'est fait avec le CWS-21, une échelle en 21 items qui évalue les six dimensions suivantes du syndrome de sevrage : dépression-anxiété; besoin urgent de fumer; irritabilité-nervosité-impatience; appétit-prise de poids; insomnies; difficultés de concentration (voir Appendice 8). Cette échelle a été conçue spécifiquement pour la recherche et l'évaluation des traitements du tabagisme. Elle a été développée et validée en français (Etter, 2005), et validée en anglais (Etter & Hughes, 2006). Les valeurs de cohérence interne (alpha de Cronbach) sont entre *0,83 et 0,96* et des corrélations test-retest de *0,60 à 0,71*.

Traitement

Le neurofeedback est un processus graduel d'apprentissage du fonctionnement du cerveau. Suivant le protocole SMR-bêta, les fréquences thêta/alpha sont inhibées, et les fréquences bêta

(15-18) ou SRM (12-15) encouragées. Les participantes se sont présentées en moyenne trois fois par semaine dans un bureau de psychologue à Pointe Claire pour des séances d'entrainement d'une durée d'une heure. Avant d'entamer l'entraînement, des électrodes étaient posées à deux endroits sur le cuir chevelu (C3 et C4) selon le système international 10-20 (Jasper, 1958) et maintenues en place à l'aide d'une pâte adhésive. Les électrodes sur les lobes d'oreilles ont servi de références et de mise à la terre. Les électrodes étaient ensuite insérées dans une boîte têtière reliée à un système d'amplificateurs (le Procomp Infiniti de Thought Technology) qui digitalisait les signaux qui ont été envoyés à un ordinateur où un logiciel (Biograph Infiniti v. 5.1.2) enregistrait les ondes cérébrales. Les changements dans l'activité cérébrale se font par apprentissage en utilisant la rétroaction (feedback). Ainsi, le signal est traité et il fournit le feedback approprié montré sur l'écran de l'ordinateur. La rétroaction (feedback) des signaux du corps (bio/neuro) est considérée comme du renforcement positif et est révélée au participant par moyen d'un jeu à l'écran et par de la musique. En séance d'entrainement, la personne doit arriver à se concentrer pour diminuer les ondes thêta/alpha ciblées, et augmenter les ondes SRM. Quand elle arrive à le faire, le jeu avance et la musique joue. Si elle n'arrive pas à produire les ondes désirées, le jeu et la musique arrêtent. De cette façon, les participantes de cette étude ont appris comment contrôler leurs ondes cérébrales pour mieux gérer leur attention. Les séances ont terminé quand les scores d'attention soutenue sur l'IVA+Plus se sont normalisés, soit de 12 à 14 rencontres.

Considérations éthiques

Étant donné que le neurofeedback est une intervention thérapeutique peu connue, afin de bien informer les participantes, celles-ci ont reçu une description détaillée du traitement et une présentation au préalable de l'équipement utilisé afin que leur droit à un consentement libre et éclairé soit respecté. L'enregistrement de l'activité cérébrale est une technique non invasive, car

les électrodes sont d'application externe seulement. Il pourrait y avoir un risque de fatigue lors des sessions alors des pauses ont été prévues. De plus, une évaluation avec le qEEG a été incluse pour s'assurer que le protocole utilisé n'était pas contre-indiqué; par exemple, par la présence d'un excès d'ondes bêta à C3 et C4, car un utilisateur avec un tel profil risque d'avoir peu de résultats. Les effets secondaires indésirables rapportés par la recherche (p. ex., maux de tête légers, nausées) semblent être rares et réversibles avec le temps (Sherlin, Arns, Lubar, & Sokhadze., 2010), mais il est fortement recommandé qu'une évaluation électrophysiologique soit complétée avant même d'entamer un traitement pour minimiser les possibilités de difficultés, et pour éviter un traitement inefficace (Hammond & Kirk, 2007).

Résultats

Deux types d'analyses ont été effectués. L'utilisation de mesures répétées (le CDS-5 et le CWS-21) a permis l'inspection visuelle de graphiques représentant les données pour chacune des phases du protocole (voir Figures 1 à 4). Cette évaluation s'est fait utilisant quatre critères d'interprétation : un changement de moyenne (comparer les moyennes entre les deux phases); un changement de niveau (les scores diminuent soudainement), un changement de tendance/pente; et la rapidité (ou latence) du changement (la vitesse à laquelle le changement survient à la suite de l'intervention). Les graphiques ont été construits utilisant le logiciel Single Case Visual Analysis Package (SCVA) de Bulté et Onghena (2012). Ce logiciel inclut plusieurs aides visuelles (comme p.ex., une ligne horizontale au niveau de la moyenne) pour faciliter la comparaison entre les deux phases de l'étude.

L'inspection visuelle semble indiquer que le niveau de dépendance à la nicotine (CDS-5) n'est pas stable pour les participantes pendant la phase A. En effet, trois des quatre participantes (VB, CR et MT) ont vécu une diminution des niveaux de dépendance initiale. Il y a eu, par contre, une

stabilisation ou une augmentation des scores pendant la dernière partie de la phase A (niveau de base) juste avant l'introduction du traitement qui visait l'amélioration de l'attention. La quatrième participante (JW) a démontré une augmentation de ses scores sur le CDS-5 à partir du premier jour. (Pour le devis à cas unique, un changement de direction de la pente met en évidence l'effet de la variable indépendante sur la variable dépendante même si le niveau de base n'est pas stable). Chez trois des quatre participantes (VB, CR et JW), on observe une baisse de la moyenne de la mesure de dépendance à la suite du traitement en neurofeedback. Il y a également un changement éventuel de la direction de la pente/tendance (la deuxième section de chaque phase) pour chaque étude de cas dans la direction espérée.

L'inspection visuelle des graphiques pour le CWS-21 (les symptômes de sevrage) indique qu'il y a eu peu de changement d'une phase à l'autre pour cette mesure chez les trois participantes qui ont réussi à diminuer leur dépendance. La dernière participante (MT) qui n'a tout de même pas réussi à diminuer la moyenne de sa dépendance à la nicotine a vécu une diminution importante de ses symptômes de sevrage pendant ce traitement qui améliorait son attention.

Afin de documenter davantage l'information issue de l'inspection visuelle, le Tau-U de Parker et Vannest (2009) a été calculé en utilisant une calculatrice en ligne (Vannest, Parker, & Gonen, 2011). Cette méthode d'analyse statistique non paramétrique, spécialement développée pour les études de cas multiples, mesure l'ampleur de l'effet et en même temps contrôle un niveau de base non stable. Le Tau-U peut indiquer le pourcentage de scores indiquant une diminution dans la phase intervention, malgré la présence d'une tendance dans la phase A ou non. (Dans cette recherche, un niveau de base a dû être corrigé avant la comparaison entre les deux phases pour le CDS-5.) Les résultats pour chaque cas sont : VB = *-74%,* CR= *-63 %*; JW = *-72%*; MT = *-8 %*. À l'exception de MT, ce sont des changements positifs modérés, mais significatifs selon un standard établi (> .4) par Parker et Vannest (2009). Une moyenne pondérée pour les quatre cas

uniques était : un Tau-U de *-0,5346*; un score Z de *-5,9614*; un intervalle de confiance de *-0,3587* à *-0,7106* à *90* %; et une valeur-p de *0*.

Quant au CSW-21, deux niveaux de base ont dû être corrigés par le logiciel et ensuite les comparaisons ont été effectuées. Les résultats sont présentés au Tableau 3 (p. 70). La moyenne pondérée pour cette variable était : un Tau-U de *0,2797*; un score Z de *-2,611*; un intervalle de confiance de *-0,1035* à *-0,4559* à *90* %; et une valeur-p de *0,0090*. Par rapport aux sous-tests du CSW-21, seulement des mesures d'envie (*craving*) ont diminué de façon significative suite à l'introduction du traitement, et seulement chez les deux participantes qui ont rapporté un nombre élevé de symptômes de TDAH.

Pour l'évaluation de l'abstinence, la FDA recommande une abstinence complète pendant quatre semaines pour établir l'efficacité d'un traitement de cessation (Hughes et al., 2003). Un suivi dix semaines après la fin du traitement a démontré qu'une participante (CR) avait rencontré ce standard. Deux autres (VB et MT) ont rapporté une dépendance à la nicotine telle que mesurée par le FTND significativement moindre qu'au début de l'étude. Une participante (MT) n'a pas donné suite aux appels de la chercheure.

Discussion

Cette étude à cas uniques avec niveaux de base multiples visait à déterminer si la combinaison d'un entraînement en neurofeedback et l'utilisation d'un timbre de nicotine pouvait améliorer la cessation du tabagisme chez des adultes avec un TDAH. Ces personnes sont davantage aux prises avec la dépendance à la nicotine. Des études antérieures utilisant une combinaison de traitements traditionnels pour le TDAH, c.-à.-d. les psychostimulants, avec le timbre de nicotine ont vu une exacerbation des effets secondaires et des symptômes de sevrage, ce qui a probablement nui à l'effort de diminuer l'utilisation de cigarettes. Le neurofeedback, comme traitement non

pharmacologique déjà connu pour les difficultés d'attention, évite ces complications. Trois des quatre participants ont réussi à diminuer d'une façon modérée, mais significative leur dépendance à la nicotine, pendant la phase intervention de l'étude, sans aggraver les symptômes de sevrage. Les résultats suggèrent que le neurofeedback SMR-bêta peut potentialiser l'utilisation du timbre de nicotine et contribuer à l'arrêt du tabagisme.

Toutes les participantes se sont améliorées sur des mesures d'attention soutenue au cours de l'étude, mais cette amélioration n'était pas constante. À certains moments les scores étaient en dessous des scores initiaux au début de l'étude. Plusieurs facteurs expliquent ce fait. La dépendance n'est pas un phénomène uniquement physiologique. Les perceptions de l'individu face à sa dépendance à la cigarette, l'impact de facteurs psychosociaux, et l`hétérogénéité du diagnostic de TDAH ont eu des effets potentiellement considérables sur non seulement l'amélioration de l'attention, mais également sur les variables dépendantes. Par exemple, le rôle du besoin urgent de fumer (*craving*), un élément qui prend de plus en plus d'importance dans la recherche sur la sévérité de la dépendance, a une relation complexe avec l'attention (Canterberry et al., 2013). Dans cette étude, la mesure du besoin urgent de fumer (incluse dans le CWS-21) s'est améliorée, mais seulement chez les deux participants qui ont rapporté plus de symptômes d'impulsivité sur l'ASRS v1.1. Il est alors difficile de conclure que c'était uniquement l'amélioration de l'attention visée par le protocole SMR-bêta qui a produit les effets observés.

Les résultats obtenus doivent être interprétés avec prudence en raison des limites importantes de cette étude. Un devis à niveaux de base multiples comporte certaines limites inhérentes à la généralisation des résultats, surtout étant donné le petit échantillon de participants, toutes des femmes. La validité des mesures autorapportées est parfois contestée dans la recherche des abus de substances et il a été impossible de contrôler totalement l'utilisation du timbre de nicotine. La recommandation est d'utiliser une mesure physiologique dans la mesure du possible (Patrick et al.,

1994). Finalement, la méthode statistique employée (le Tau-U) est une approche encore peu explorée dans la recherche des cas uniques. Toutefois, les résultats de la présente étude sont similaires aux études précédentes de cessation tabagique utilisant un traitement pharmacologique pour le TDAH combiné à un timbre de nicotine (Winhusen et al., 2010).

En conclusion, les résultats modérés, mais significatifs de cette étude appuient l'hypothèse que le neurofeedback, malgré les mécanismes thérapeutiques inconnus, pourrait améliorer l'attention chez les personnes avec un TDAH et favoriser la diminution de la dépendance à la nicotine en combinaison avec l'utilisation d'un timbre de nicotine.

Introduction

Attention deficit hyperactivity disorder (ADHD) and smoking are among the most common and most costly psychiatric and behavioural problems facing society today (Rehm & Perron, 2006). ADHD is a neurobehavioural disorder that involves inappropriate attention, hyperactivity and impulsivity that interferes with functioning or development. Worldwide, it is estimated that 5.3 % of children and adolescents have ADHD (Polanczk, Silva de Lima, Horta, Biederman, & Rohde, 2007) and 4 to 4.5% of adults (Kessler, Chiu, Demler, & Walter, 2005). A more recent survey by the United States Center for Disease Control revealed that 11% of American school-aged children have been diagnosed with ADHD by a health-care provider (Visser et al., 2014). It was long considered a disorder of childhood but it is now recognized that 40 to 60 % of the children diagnosed with ADHD continue to meet diagnostic criteria for the disorder in adulthood (Barkley, Fischer, Smallish, & Fletcher, 2002; Biederman, Petty, Evans, Small, & Faraone, 2010; Kessler et al., 2010). A consensus statement of the world's leading researchers for ADHD concluded, "there is no doubt that ADHD leads to impairments in major life activities, including social relations, education, family functioning, occupational functioning, self-sufficiency, and adherence to social rules, norms, and laws" (Barkley et al., 2002, p. 90).

More than 37,000 Canadians died prematurely due to tobacco use in 2007 and there is strong scientific evidence that smoking is related to more than two dozen diseases and conditions (Statistics Canada, 2011). ADHD adults and adolescents are more likely to start smoking at an earlier age and progress to regular use younger (Breyer, Burgetova, & Roper, 2009; Galéra, Fombonne, Chastang, & Bouvard, 2005; Molina & Pelham, 2003). They smoke significantly more than the general population and there is a linear relationship between ADHD symptoms and number of cigarettes smoked (Pomerleau, Downey, Stelson, & Pomerleau, 1995). The withdrawal

symptoms are more severe (Knott et al., 2008), they relapse more quickly (Humfleet et al., 2005) and fewer of these individuals, men in particular, quit definitively (McClernon & Kollins, 2008).

What is the connection between nicotine addiction and ADHD? In some substance use disorders ADHD as a risk factor is almost always accounted for by the presence of other co-morbidities. But in the case of nicotine use, ADHD appears to be an independent risk factor (Ameringer & Leventahl, 2013; Biederman et al., 2006a; Breyer, Burgetova, & Roper, 2009; Pingault et al., 2013; Pomerleau et al., 2003; Wilens et al., 2008). The significant individual, social and health costs of the co-morbidity between smoking and ADHD justify the growing number of research projects seeking to elucidate the impact of early, as well as concurrent, treatments for ADHD on smoking behaviour. Although answers are not yet conclusive, understanding the impact of nicotine, a stimulant, on the inattention aspect of the disorder may provide a clue to solving the puzzle.

Many believe that prior treatment for ADHD can alter interactions between the two disorders and improve eventual smoking cessation outcomes. This belief is grounded in the numerous studies that have reported a decrease in overall substance use, including tobacco, following medication treatment in childhood (Chang, 2014; Wilens et al., 2008). Nonetheless, not all studies have reached these conclusions. One of the most comprehensive studies in the field (*the NIMH Collaborative Multisite Multimodal Treatment Study of Children with ADHD*) revealed that early stimulant treatment failed to provide any protection against, nor did it contribute to, subsequent nicotine addiction in the treatment group as compared to a non-medicated control group (Molina et al., 2009).

These findings speak to the complexity of the interaction between ADHD and nicotine dependence and the importance of identifying effective and novel ways of decreasing the risk of tobacco use conferred by the disorder. To that aim, investigations have focused on treatments

using stimulants and nicotine replacement products alone and together (Gehricke, Whalen, Jamner, Wigal, & Steinhoff 2006; Gehricke, Hong, Whalen, Steinhoff, & Wigal, 2009; Gehricke, Hong, Wigal, Chan, & Doan, 2011). Results have been contradictory with some laboratory studies with stimulants even showing an increase in smoking (Silverstone & Dardashova, 2012). Several recent studies combined a proven ADHD treatment and a proven nicotine dependence treatment to combat smoking in affected individuals. Yet again, results were equivocal, due in part to the presence of confounding side-effects (Covey, Manubay, Jiang, Nortick, & Palumbo, 2008; Winhusen et al., 2010). Finally, the increased risk of cardiovascular issues when nicotine replacement products are used concurrently with stimulants have led to recommendations that alternative treatments be found to provide options to clinicians and patients.

Neurofeedback is an alternative non-pharmacological treatment for ADHD which seeks to regulate the electrical activity of the brain. It is considered a form of operant conditioning and as such is eminently applicable to the practice of clinical psychology (Collura, 2014). Electrodes placed on specific sites on the skull record the electroencephalographic signal beneath. The digitized signal is then transformed by a computer which feeds the information back to the user. The resulting beta, alpha, theta and delta waves can subsequently be enhanced or inhibited in order to produce the rhythms selected by the neurotherapist. The sensorimotor rhythm, or SMR, is a low beta wave that can be recorded over the motor cortex, and "is connected to the brain's intention to be still" (Collura, 2014). Learning to enhance an SMR signal is one of the main goals of neurofeedback treatment for ADHD and has garnered the greatest amount of research. A recent meta-analysis by Arns, de Ridder, Strehl, Breteler, and Coenen's (2009) reported mean effect sizes for improvements following neurofeedback treatment: including *1.02* for inattention; *0.71* for hyperactivity; and *0.94* for impulsivity. Side effects appear to be minimal and transient (Sherlin, Arns, Lubar, & Sokhadze, 2010). This study will attempt to contribute to this body of research and

provide an alternative for clinical treatment of smoking in this clientele by examining whether a known neurofeedback treatment for attention can help smokers significantly reduce their dependency on tobacco.

Theoretical Context

ADHD, Smoking and Substance Use Disorders

Although the link between ADHD and smoking is now recognized, the debate as to how they are linked continues to fuel research and the bidirectional interaction between them is constantly being revised (Gray & Uphadhyaya, 2009). More study is needed to clarify the nature of this complex relationship, but there is nevertheless sufficient evidence emerging to suggest that a unique neurobiological link may exist between the inattention aspect of ADHD and tobacco addiction (Burke, Loeber, White, Stouthamer-Loeber, & Pardini, 2007; Lerman et al., 2001; Tercyak, Lerman, & Andrain, 2002).

ADHD and its Presentations

It may be useful to first briefly review how the diagnosis of ADHD and its iterations have affected research into the condition. As of May 2013, ADHD has officially been recognized by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) as a neurodevelopmental disorder (American Psychiatric Association, 2013). Prior to that date, the DSM-IV-TR listed ADHD as part of a group of disruptive behaviour disorders that included oppositional defiance disorder and conduct disorder (American Psychiatric Association, 2000). The convergence of genetic, neuroscience and behavioural research of the last decade has culminated in the recognition that ADHD shares commonalities with other neurodevelopmental disorders such as early onset, persistence over time, a high male to female ratio, genetic and environmental interactions, and identifiable patterns of altered brain function (Taylor, 2013). There are now three “presentations” of the diagnosis (previously referred to as subtypes); inattentive, hyperactive/impulsive and combined, with six or more symptoms from each category, resulting in behaviour that is inappropriate for the developmental level of the individual and that is disruptive or causes impairment in two or more settings. Another change in the diagnosis of ADHD is the recognition that teens and adults can now be officially diagnosed as long as

symptoms are present by age 12. For those 17 or older, only five symptoms from each category are now necessary. Examples of the symptoms of inattention are: often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or with other activities; often has trouble holding attention on tasks or play activities; often does not seem to listen when spoken to directly; often does not follow through on instructions. Examples of the symptoms of hyperactivity/impulsivity are: often fidgets with or taps hands or feet, or squirms in seat; often leaves seat in situations when remaining seated is expected; is often unable to play or take part in leisure activities quietly; is often "on the go" acting as if "driven by a motor"; often talks excessively.

First-line recommendations for treatment include stimulant medications such as methylphenidate and amphetamines, as well as targeted psychosocial interventions. Other non-stimulant medications, usually atomoxetine and the anti-depressant buproprion, can be prescribed but research has indicated that the enhancement of noradrenergic neurotransmission afforded by stimulants provides the best chance of treating symptoms pharmacologically (Kolar, Keller, Golfinopoulos, Cumyn, Syer, & Hechtman, 2008). An fMRI exploration of the effects of methylphenidate on resting brain networks confirmed its action as an indirect dopaminergic and noradrenergic agonist resulting in increased connectivity between seven different resting state networks, revealing the broad impact of the drug on the brain as a whole (Mueller et al., 2014).

The role of dopamine within the brain and its implication in many psychiatric and neurological disorders that also present with difficulties in attention and concentration is well-known. The dysregulation of the central dopaminergic system has long been suspected as the neurobiological basis of ADHD and it is for that reason that stimulants are so often initially effective given their action within this system (Hechtman, 2009). Atomoxetine is a selective inhibitor of presynaptic norepinephrine that can be used in the 10 to 30% of cases that do not respond to stimulants or

who experience unacceptable side-effects. Buproprion, also an option to stimulants, is an off-label prescription for ADHD, as it was initially approved by the FDA for mood disorders or as a smoking cessation aid. Its mechanism of action not fully understood but it is also an inhibitor (albeit a weak inhibitor) of dopamine and norepinephrine reuptake (Sharma & Couture, 2014). All of the pharmacologic treatments for ADHD have potential side effects that require monitoring by a physician. For stimulants, the most common are insomnia, nausea, decreased appetite, elevated pulse, abdominal pain and mood lability.

The changes introduced by the DSM-5 resolved certain issues pertaining to the diagnosis, but there is still enormous debate and even controversy over the way this disorder is conceptualized and evaluated (Brown, 2009). The great heterogeneity that exists across people with the diagnosis and the inconsistent responses to the first line treatments for ADHD imply more changes will be proposed. This is perhaps most evident in the discussion over what has been termed executive function abilities. Russell Barkley, one of the foremost researchers and theorists in the field of ADHD has argued that executive function problems (response inhibition, working memory, regulation of emotion, self-speech and flexibility) should be considered as core deficits of ADHD (Barkley, 1997). Although it is as yet unclear exactly how executive functions are distinct and/or related to inattention and hyperactivity/impulsivity, Barkley has stated that a primary cause of ADHD is an inhibitory control deficit. Executive function impairments most definitely influence nicotine dependence (Dolan, Bechara, & Nathan, 2008) so a discussion of smoking and ADHD cannot take place without explaining why this topic is not central this study.

There are difficulties with the definition of the term as well as a lack of universality amongst those diagnosed with the disorder. Furthermore the presence of these impairments in other mental health conditions is not negligible (Wilcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Recently, Barkley has expanded his theory and proposed that ADHD is essentially an executive

function deficits disorder which includes impairments with all or most of the following skills: self-awareness; inhibition; non-verbal working memory; verbal working memory; emotional self-regulation; self-motivation; planning and problem solving (Antshel, Hier & Barkley, 2014). He has gone so far as to suggest that the name be changed from ADHD to Executive Function Deficits Disorder (EFDD).

Furthermore, Barkley has proposed that a subset of those diagnosed with ADHD-Inattention may actually have an attention disorder that is distinct from ADHD resulting in a sluggish cognitive tempo that pervades all the individual's activities (Barkley, 2010). These individuals also have executive function impairments, albeit with a different profile. These proposals would imply a major revision of our current idea of ADHD. Despite widespread agreement that executive function symptoms form part of the presenting problems of patients with ADHD, as well as a general consensus as to their importance clinically, the need for more research precluded their inclusion as formal criteria for ADHD. For this reason, they will not be dealt with specifically in our discussion.

The obvious complexities in the conceptualisation and diagnosis of ADHD have contributed to inconsistencies in the research and difficulties in pooling results to produce effect sizes across studies. Suffice it to say that there is a longstanding debate as to the adequate assessment of ADHD for diagnostic and research purposes (Coghill & Seth, 2011). There are as of yet no definitive tests or rating scales that exhibit high enough positive predictive value to validate the diagnosis of ADHD in either children or adults (Haavik, Halmoy, Lundervold, & Fasmer, 2010). The authors concluded that cognitive tests are neither sufficient nor necessary for a diagnosis of ADHD, yet they add to the clinical understanding of individual differences within the disorder. Recommendations by these same authors for diagnosis of adult ADHD include: a comprehensive clinical interview by a clinician who is knowledgeable in terms of the most important psychiatric

conditions and their combinations; collateral information from a significant other who has preferably known the patient in childhood; rating scales and self-reports for symptom assessment such as the Adult ADHD Self-Report Scale (ASRS) or the Conners' Adult ADHD Rating Scale (CAARS); a scale for functional impairment such as the Weiss Functional Impairment Rating Scale (WFIRS) or the Wender Utah Rating Scale (WURS). A neuropsychological assessment, however, would be important to tailor treatment to the individual. A medical evaluation is absolutely necessary to rule out other conditions that could mimic ADHD symptoms (such as epilepsy or thyroid disorders) as well as allow for adequate monitoring of pharmacological treatment.

In research that relies on the participation of adolescents or adults (such as for smoking) the inclusion criteria used in the past to select participants has been a particularly thorny issue. For example, the DSM-IV-TR required that symptoms be present by age seven. It is not clear whether this was the standard in studies that investigated smoking and ADHD. In addition, while some studies required an official diagnosis made in childhood, many did not. In a review of the literature, it was noted that the *assumption* of ADHD was often made on the basis of retrospective adult self-reports of symptoms (Looby, 2008). Such self-reports are notoriously unreliable so cannot be used alone (Williamson, Combs, Berry, Harp, Mason, & Edmundson, 2014).

The outcome is that when the results of these studies are pooled, a great deal of specificity is lost. It has therefore been a challenge to achieve interpretable results in explaining the relationship between nicotine, tobacco, ADHD and its component parts. As will be seen, inattention and impulsivity appear to confer different degrees of risk for nicotine dependence, so distinguishing between the types of presentations involved is important. No firm conclusions have as of yet emerged as to the exact role each deficit plays in nicotine addiction, although there is no longer any doubt that the role of each is significant and distinct.

Role of ADHD Subtypes/Presentations and Severity of the Disorder

The distinction between the different subtypes of ADHD, inattentive versus hyperactive and impulsive has often been overlooked in the research when cohorts of ADHD patients are grouped together, yet when hyperactivity/impulsiveness and inattention are examined separately, there are different smoking outcomes associated with each dimension of the disorder (Burke, Loeber, White, Stouthamer-Loeber, & Pardini, 2007; Rodrigues, Tercyak, & McGovern, 2008). These symptoms differ psychometrically and may stem from distinct genetic influences. Each dimension of the disorder contributes in unique ways to eventual tobacco addiction.

Lerman et al., (2001) reported that smoking was associated with ADHD inattentive symptoms whereas hyperactive symptoms were not. Participants recruited for a smoking cessation program from the general population were classified according to a self-report of inattention and/or hyperactivity symptoms. The analysis found a correlation between the inattention symptoms and the use of cigarettes. This results has been reported in a number of studies (Fuemeller, Kollins & McClernon, 2007). In addition, participants endorsed smoking for stimulation purposes to alleviate problems with inattention. In another study, inattention was found to be associated with ADHD individuals taking up smoking in early adolescence, whereas hyperactivity/impulsivity was more closely associated with smoking initiation in early adulthood (Rodriquez, Tercyak, & Audrain-McGovern, 2008). When examined carefully, a reviewer concluded that hyperactivity/impulsivity was not consistently related to early cigarette use but is more often seen as a contributor to later heavy smoking, which in turn is related to the presence of conduct disorder or other psychosocial factors such as family smoking (Looby, 2008). Impulsivity has however a direct effect on the ability to quit smoking once it is a habit (Covey, Manubay, Jiang, Nortick, & Palumbo, 2008). Inattentive symptoms of ADHD on the other hand, are directly and systematically impacted by nicotine, whether administered clinically or obtained through cigarette smoking

through the stimulation of nicotinic acethylcholine receptors (Burke, et al., Levin et al., 1996). In a longitudinal study examining these relationships, inattention even appeared to predict the severity of the nicotine dependence (Pingault et al., 2013). In a national sample of American smokers with ADHD, results showed that after controlling for hyperactivity-impulsivity, only inattention was associated with smoking (Ameringer & Leventhal, 2013).

Severity of ADHD symptoms, as measured by the number of ADHD symptoms endorsed by respondents, were proportionally associated with reported tobacco use in a sample of 334 college students (Upadhyaya & Carpenter, 2008). In the Lerman et al. (2001) study, severity of the inattentive symptoms even in a "normal" population was correlated with greater urges to smoke. It has been argued that some form of functional impairment can occur even when there are insufficient symptoms to meet the threshold for a diagnosis, and that these individuals merit being identified for treatment (Faraone, Wilens, Petty, Antshel, Spencer & Biederman, 2007). This is especially the case in adults who may or may not have been diagnosed as children but who's ADHD has lessened with age. In two separate studies that followed participants for an average of 11 years, 65% of the boys and 33.3% of the girls diagnosed in childhood no longer met the DSM-IV-TR criteria in young adulthood (Biederman, Petty, Evans, Small, & Faraone, 2010; Biederman, Petty, O'Connor, Hyder, & Faraone, 2012). Yet 78% of the boys and 77.1% of the girls still met at least one of the definitions of persistence devised by the authors. The definition of persistence varies from one researcher to another, but in this case persistent ADHD included cases that: 1) still met full criteria for the diagnosis, 2) met more than half (termed symptomatic ADHD) 3) did not meet those requirements but still exhibited impaired functioning and 4) were not impaired but were medicated. One of the primary dysfunctions associated with the persistence of symptoms was smoking. In the study looking at boys, 38% smoked at the 10-yr follow-up compared to 15% of the control group. For the girls, 11% were smoking 11 years later as compared to 4% of controls.

Other than the fact that the increased risk for smoking within this group suggests that these individuals should also be targeted for treatment, there appears to be some indication that individuals with more severe forms of ADHD (endorsing a greater number of symptoms) may need a treatment approach that is different from the less symptomatic group. One study found that ADHD individuals with higher levels of attentiveness actually smoked more rather than less when treated with stimulants (Poltavski & Petros, 2006).

Role of Comorbidities

At the outset, nicotine dependence was not the focus of addiction studies involving individuals with ADHD; probably because of the ubiquitous presence of smoking and the massive use of cigarettes by people diagnosed with mental health problems in particular. It is impossible to discuss the impact of ADHD on nicotine dependence without trying to account for the impact of the many significant comorbidities of the disorder on tobacco use. Of all cigarettes produced in the U.S., 44% are smoked by people with psychiatric disorders (cited in Mason, Walker, Wine, Knoper, & Tercyak, 2007). In one sample of patients with substance abuse and psychiatric disorders including ADHD, nearly all of the participants (98.6%) smoked (Abrantes, Brown, & Tomlinson, 2003). Nor was ADHD always examined in population and clinic-based studies of smoking, possibly because it was considered a disorder of childhood that faded with maturity and could therefore not be highly relevant in an older smoking population (McClernon & Kollins, 2008). Eventually, it became clear that ADHD continues into adulthood and that people with ADHD have a greater risk of developing subsequent substance use disorders of all sorts including alcohol, marijuana, cocaine, methamphetamines and cigarettes amongst others (Biederman, Wilens, Wick, Faraone, & Spencer, 1998; Charach, Yeung, Climans & Lillie, 2011). Disentangling nicotine addiction from the influence of other comorbidities was essential to

recognize the association between ADHD symptoms and nicotine use, as well as understanding why this association exists.

A number of hypotheses were proposed to explain the connections between substance use disorders, smoking and patterns of psychopathology in this group of people. The hypotheses themselves changed depending on which symptoms of ADHD were examined (Tercyak et al., 2002), which substance was being investigated (Latimer, Ernst, Hennessey, Stinchfield, & Winters, 2004), which additional co-morbidities were present (Lerman, 2001; Looby, 2008; Newcorn, 2008), and at what point in the lifespan treatment for ADHD was initiated, if at all (Manuzza et al., 2008; Dalsgaard, Mortensen, Frydenberg, & Thomsen, 2014).

Initially, the assumption was that there was a common psychosocial cause, such as familial dysfunction, underlying not only smoking and attention disorders but all substance use problems as well as comorbidities such as conduct disorder and oppositional defiance disorder (Biederman et al., 1995; Scahill et al., 1999). This belief was based on the fact that certain disorders coexist to a remarkably high degree within families that exhibit major dysfunction such as drug and alcohol abuse, exposure to violence, poor nutrition, and so on (Dolan et al.,2008; Wilson, 2007; Thapar, Cooper, Eyre, & Langley, 2013). For example, cocaine use and ADHD are highly correlated (Lambert & Hartsough, 1998) and are often accompanied by family pathology. The same is true of conduct disorder and cocaine use, as well as conduct disorder and ADHD – all are highly correlated and accompanied by high levels of family distress (Modesto-Lowe, Danforth, Neering, & Easton, 2010). The initial characterisation of behaviours resembling ADHD as a defect of "moral control" may have contributed a long standing bias to inquiries carried out thereafter (Charach et al., 2011). Even though familial heritability (both genetic and environmental) continues to be an element that confounds research into the comorbidities associated with ADHD, a consensus is emerging that the pathologies that co-occur within these families are the result of

common underlying causal factors and not vice versa although there is a great deal of interplay between them (Thapar et al., 2013). These as yet to be identified causal factors then contribute to promote more risk factors such as poor prenatal care, damaging parenting practices, socioeconomic hardship and instability, participation in deviant groups, etc., which can then become targets for interventions that will mediate the correlations that exist.

Ultimately, it was shown that ADHD as a risk factor for later cocaine use can almost completely be accounted for by the presence of conduct disorder (Barkley, Fischer, Smallish, & Fletcher, 2004) although this finding does not always apply to young women (Galéra et al., 2004). Disruptive behaviour disorders have been implicated in the increased risk for alcohol, marijuana, and amphetamines in this population (Lee, Humphreys, Flory, Liu, & Glass, 2011). This is not, however, the case for smoking and ADHD, which appear to have an exclusive relationship which is independent of conduct disorder even though they are highly correlated with them (Ameringer & Leventhal, 2013; Charach et al., 2011). A very recent longitudinal study that tracked 1803 participants over 15 years found that only inattention contributed to smoking dependence in adulthood whereas other substance abuse increased only when the diagnosis was associated with childhood oppositional defiance disorder (Pingault et al., 2015).

There are consistent findings that depression and anxiety alone are risk factors for smoking (Lerman et al., 2001, Mason et al., 2007). Many such mental health disorders are present when ADHD is found. A Montreal study reported that 71.9% of ADHD adults had one or more Axis 1 disorders, and 50.9% had one or more Axis II disorders (Cumyn, French, & Hechtman, 2009). In another study, this time within a sample of substance abusing adolescents, different patterns of addictions were seen depending upon whether ADHD comorbid conditions were externalizing disorders such as oppositional defiance disorder or internalizing disorders such as depression (Abrantes et al., 2003). The question is that without the contribution of the comorbid pathologies,

does ADHD still confer increased risk for smoking? In the Montreal study, when compared with a group of non-ADHD patients also referred for mental health issues, the ADHD patients exhibited greater nicotine dependence. Eventually, two major studies that controlled for underlying psychopathology indicated that of all substance use disorders considered; only the lifetime risk for nicotine dependence was greater for those with ADHD (Biederman et al., 2006b; Molina & Pelham, 2003.)

Role of ADHD Medication in Substance Use Disorders and Smoking

Another hypothesis that motivated a great deal of research into ADHD and substance use posited that stimulant treatment in childhood altered brain functioning in such a way that it actually predisposed people to addictions later in life (Lambert & Hartshough, 1998; Manuzza et al., 2003). Subsequent research has not always supported this hypothesis (Barkley, Fischer, Smallish, & Fletcher, 2003; Molina et al., 2007). In fact, it is the opposite that has garnered the most evidence to date; i.e., childhood treatment for ADHD can reduce the risk for many substance use disorders (Chang et al., 2014; Wilens, Faraone, Biederman & Gunawardene, 2003; Wilens et al., 2008). The use of stimulants, as well as the non-stimulants atomoxetine and buproprion (usually prescribed for depression and mood issues) frequently show decreased substance use subsequent to treatment, although in the case of severe drug toxicity, results continue to be mixed (Levin, 2007). There are nonetheless several important studies reporting that medications do not protect ADHD children from developing addictions as adults. They appear to confirm however that they do not *contribute* to subsequent drug abuse (Faraone, Wilens, Biederman, & Adamson, 2007; Golden, 2009; Molina et al., 2013). An exception is the research that suggests that when ADHD treatment is only initiated in young adulthood, the risk of future polysubstance abuse is actually increased although more research is needed in this area (Kollins, 2008).

Another exception appears to be the risk for nicotine dependence. Research findings have found that prior and concurrent pharmacological treatment for ADHD can decrease or *increase* the risk of tobacco use (Golden, 2009; Gray & Upadhyaya, 2008). A two year follow-up of high school students with ADHD found that those who were medicated smoked less than those who were not (Whalen, Jamner, Henker, Gehricke, & King, 2003). A 2013 study that compared ADHD adolescents treated with extended-release methylphenidate to non-ADHD and non-treated ADHD comparators found that the non-treated ADHD group had higher levels of cigarette smoking (Hammerness et al., 2013). A neutral finding was reported in a multi-national European study of stimulants and substance use disorders in over 700 adolescents. There was a protective effect for other substance use disorders, but not for nicotine (Groenman et al., 2013). Another European study investigating methylphenidate in adult ADHD participants who were already smokers saw an increase in smoking two weeks after treatment initiation, as well as increased tobacco consumption three months later (Bron et al., 2013). In another trial, when several ADHD medications (methylphenidate, atomoxetine, dextroamphetamine, etc.) were compared to placebo, the medications reduced salivary cotinine levels in participants - supporting the contention that medication might improve smoking reduction (Gehricke et al., 2011).

In an attempt to isolate the effects of methylphenidate on nicotine use, a study was conducted on a group of smokers without ADHD, aged 17 to 27 years. Participants actually increased smoking following ingestion of methylphenidate, prompting the researchers of that study to speculate that methylphenidate increased the reinforcing effects of the nicotine through a synergistic effect of the drugs on dopamine levels (Rush et al., 2005). In a follow-up study, the same researchers administered methylphenidate to one group of healthy smokers and atomoxetine to another group hypothesizing that only the methylphenidate would increase smoking since atomoxetine is a norepinephrine transport inhibitor which does not have the same additive effect

on dopamine. There was a dose-dependent increase in the number of cigarettes, puffs and carbon monoxide levels for the methylphenidate (Vansickel, Stoops, Glaser, & Rush, 2007). (Both of the drugs were sufficiently active as to decrease food intake.) Varying results across studies only emphasize the complexity of the interactions involved.

Differential efficacy of medication in the treatment of nicotine dependence according to race and ethnic differences was highlighted in a multi-site, randomised controlled trial with OROS-methylphenidate (OMPH) and the nicotine patch, which resulted in a significantly higher rate of four-week complete abstinence for non-Caucasians (Covey et al., 2010). Gender is another factor that should be included in all analyses because of the evidence that has begun to accumulate indicating that females with ADHD have different patterns of tobacco addiction and greater withdrawal symptoms upon abstinence (McClernon et al., 2011).

The fact that there are no clear conclusions as to whether prior or even current treatment for ADHD can protect affected individuals from being more vulnerable to nicotine dependence suggests that there is more to be understood in the etiology of smoking behaviour in this patient group. As has already been suggested, nicotine appears to relieve their symptoms and may be a significant reason such individuals are drawn to cigarette smoking.

Self-Medication Theory

The theory that those with ADHD are self-medicating with cigarettes stems from two sources of repeated findings within the research. One is that the ingestion of nicotine actually improves the overt symptoms of the disorder as well as the emotional dysregulation and cognitive deficits experienced by those with ADHD, so when they experience the benefits of smoking they are reinforced to continue (Poltavski & Petros, 2005). The latter two symptoms are often unaffected or even aggravated with the use of stimulants (Potter, Schaubhut, & Shipman, 2014). The other theory is that once smoking has begun, possibly due to an impulsive urge to take risks, it is

maintained in order to avoid aversive withdrawal symptoms that are more severe than in smokers without ADHD. One would assume therefore that these outcomes are due to a brain-based link between ADHD symptoms and nicotine, and that ADHD medication could be compared to nicotine in terms of impact on those symptoms.

It has been proposed that the underlying mechanisms of ADHD and the physiological effects of nicotine share a common neurotransmitter system (Wilens et al., 2008). Recent neurogenetic studies indicate that cholinergic systems might also be altered in persons with ADHD, further explaining the connection between cigarettes and ADHD (Potter, Newhouse, & Bucci, 2006; Bacher, Rabin, Woznica, Sacco, & George, 2010). Central cholinergic systems are purported to sustain attention and working memory, two cognitive capacities known to often be impaired in ADHD patients. Krause et al. (2000), using positron emission tomography, showed similar effects of nicotine and methylphenidate on the dopamine transporter protein. As such, and given the significant number of ADHD patients who do not respond positively to the well-known stimulants in use, nicotinic agents are being developed as alternative pharmacological treatments for ADHD.

Nicotine when administered has long been shown to have a favourable impact on both dimensions of ADHD (Potter et al., 2014). When Gehricke et al. (2006) administered nicotine to non-smoking and smoking participants with ADHD, only inattentiveness significantly improved in both groups, yet in a replication the trial both dimensions of the disorder were significantly improved (Gehricke et al., 2009) Both studies used self-report to track the changes and inattentiveness was defined as difficulty concentrating and forgetfulness, as opposed to restlessness, impulsivity and impatience. In a study dating back to 1996, nicotine improved performance and mood within a cohort of ADHD participants on a number of cognitive tasks as well as one mood measure and one measure of global impairment (Levin et al., 1996). Eleven non-smokers and six smokers were compared following administration of a nicotine or placebo

patch following a night of abstinence. The improvement seen in the non-smokers confirmed that the overall benefits were not only due to a lessening of withdrawal symptoms. Two of the non-smokers experienced side-effects (nausea and dizziness) important enough that the patch had to be removed. In another group, this time of non-smoking ADHD adolescents, a single low dose of nicotine significantly improved performance to varying degrees on a variety of cognitive measures (Potter & Newhouse, 2008). The improvements were largely the equivalent to their performance with a dose of methylphenidate except for the well-known Stroop test. The authors reported that the reduction of the Stroop effect was significant only with the nicotine patch, not the methylphenidate. This was in contrast to the Levin et al. study that had not seen any significant change in the Stroop effect in either group. Furthermore, the participants reported less irritability and less anxiety (similar to the Levin et al. study) in comparison to the methylphenidate trial. It should be emphasized however that of the eight participants in the study, three were excluded due to the side-effects of the initial dose of nicotine, and six had been regularly taking medication for ADHD (not administered the day of the nicotine patch trial) - possibly altering the results. Although this study examined a one-time dose effect, results may not be maintained with regular use of nicotine. An animal study using mice which were given the drug found that the reaction to the substance changed during treatment (Leach, Cordero & Gould, 2013). Initially, the animals showed improvements in performance of a behaviour associated with inhibitory control, but the effects were not maintained with chronic consumption.

Smoking cessation has been shown to produce greater increases of depressed mood, insomnia, irritability and difficulty concentrating for those with greater levels of ADHD symptoms (Lerman et al., 2001; Pomerleau et al., 2003). The nicotine study by Gehricke et al. (2009) followed 25 smokers and 27 non-smokers with ADHD in a smoking cessation program using either a patch or a placebo patch. All of the participants were treated during a two day non-smoking trial following a

wash-out period if they were medicated. The authors reported that although negative emotions such as anger and stress were reduced, the smoking participants did not report withdrawal relief on a measure designed to track symptoms such as craving, appetite, physiological and psychological withdrawal. The authors did point out that salivary cotinine levels in the smoking participants indicated that they might have been unable to totally refrain from smoking during the required abstinence period, so the relief they might have experienced with the patch was undermined.

In a follow-up study examining the effects of stimulant medication on the same measures, ADHD medication alone appeared to promote a reduction of withdrawal symptoms (with the exception of craving) accompanied by a reduction in salivary cotinine measures (Gehricke et al., 2011). Again, this is in contrast to the findings of the earlier study which included four phases of: 1) a combination of stimulant and patch; 2) patch only ;3) placebo and stimulant and; 4) placebo only. No real effects on emotional regulation were shown with the patch, although core ADHD symptoms improved in the first three conditions. The researchers had expected to see the potentiating effects of nicotine due to the medication. They speculated that perhaps the stimulant dosages were too low. These were trials that lasted no longer than two days each, which may not have generated sufficient opportunity to observe more interaction effects. (Given that these trials were only investigating the effects of nicotine on symptoms, no one was actually trying to quit smoking either, which might have altered symptoms further.)

An overnight abstinence from smoking study looking at a group with ADHD and a group without the diagnosis showed that the ADHD group had greater decrements in performance on a continuous performance test although they did not differentiate on reports of withdrawal (McClernon & Kollins, 2008). A longer abstinence period (12 days) however also showed a significant worsening of withdrawal severity among ADHD smokers, *independent of ADHD*

symptom change (McClernon et al., 2011). The latter study employed a self-report of ADHD symptoms to track changes, which might have been less reliable.

Smoking Cessation with ADHD Medication and an NRT

Currently, the gold standard treatment for ADHD is psychostimulants. A randomised, placebo controlled trial, in an attempt to potentiate a known smoking cessation treatment with a known ADHD treatment, examined the use of osmotic-release oral system methylphenidate (OMPH) in combination with a nicotine replacement treatment (NRT). No difference was found in smoking cessation outcome for ADHD adults when compared to a placebo but there was a significant reduction in smoking in both groups (Winhusen et al., 2010). Furthermore, the OMPH group reduced their cigarettes per day to a slightly greater degree than the placebo ADHD group. There was no indication whether withdrawal symptoms were impacted differently, but it was reported that the OMPH group experienced significantly higher levels of dyspepsia, decreased appetite, increased heart rate and palpitations. When the results for the same cohort were re-analysed looking at racial/ethnic differences, there was a significant difference favouring cessation in the non-Caucasian/ethnic group (Covey et al., 2010). The authors were not able to explain this differential efficacy, but there are ethnic differences in the way cultures view all of the symptoms associated with ADHD, and other studies have shown that race can be a protective factor in smoking (Burke et al., 2007).

Interestingly, in another secondary analysis of the study results, withdrawal symptoms were found to be being stronger among the OROS treated patients than among the placebo treated patients. However, when the overlap of ADHD symptoms and withdrawal symptoms was controlled for, withdrawal symptoms (other than craving) were reduced in the medication group (Berlin, Hu, Covey, & Winhusen, 2011) A further analysis revealed that the most significant withdrawal symptom associated with *successful* abstinence in this study was that of craving

regardless of group membership, but ADHD participants experienced higher levels of craving overall. Although in this study, craving did not appear to be associated with either the treatment or the placebo group, the relationship between methylphenidate and craving aggravation had been previously established with immediate release methylphenidate (Rush et al., 2005; Vansickel et al., 2007).

Yet another post hoc analysis considered ADHD subtype as a factor influencing abstinence outcome (Covey et al., 2011). It was found that level of nicotine dependence (as measured by the Fagerström Test for Nicotine Dependence) was an additional confounder. There was a treatment effect according to subtype only when nicotine dependence was high (≥ 7), at which point ADHD with inattention did more poorly with OMPH and the patch versus the nicotine patch alone, whereas ADHD with combined symptoms did better with the conjoint treatment. They did not attempt to disaggregate racial/ethnic groups by ADHD subtype, nor did they report on the association of craving with ADHD subtype in this analysis. It is possible that the adverse effect of the medications may have contributed to and confounded the already difficult withdrawal symptoms experienced by all the participants, but may have had an even greater impact on the inattention group, thereby neutralising any advantage the change in ADHD symptoms might have given them over the non-medicated ADHD group just as in the original study.

In summary, these very important reports of a trial that combined OMPH with a nicotine patch found the following: a significant level of withdrawal symptoms in the ADHD group; a significant reduction in ADHD symptoms in the OMPH group overall; significant side-effects in the medication group; greater abstinence for non-white smokers with the medication; negative outcomes for highly dependent inattentive subtype smokers; and no effect on craving in ADHD participants when the overlap between withdrawal symptoms and ADHD symptoms are considered.

Given the laboratory studies that have shown increased smoking in adult non-ADHD participants when stimulants are used, some researchers recommended that non-stimulants should be prescribed for ADHD in smokers. One study combined bupoprion and nicotine patches. Those with ADHD showed lower abstinence rates than non-ADHD participants, but in this case, the smokers with inattention had better odds of quitting with the medication than the smokers with hyperactivity/impulsivity (Covey et al., 2008). This highlights yet again the divergence of findings between the two dimensions of the disorder. The reported side-effects of the medication were significant in this study (sleep disturbance: 37.9% of participants; dizziness: 36.5%; agitation 27.1%; skin rash: 22.5%; headache: 20.9%, nausea: 19.4%). In conclusion, treatments for ADHD symptoms can also have a significant impact on the dependence and withdrawal symptoms of smokers. An alternative treatment that would not produce the potentially confounding effects one sees with medication would prove clinically useful for this population.

Neurofeedback and Attention

Neurofeedback represents a brain-based alternative that has few if any side-effects when administered properly by appropriately trained practitioners. It can potentially reduce ADHD symptoms, particularly in the ADHD-Inattentive subtype, without aggravating withdrawal symptoms. Also known as electroencephalographic (EEG) biofeedback, it is a non-invasive and alternative treatment for a number of conditions, but it is primarily for the treatment of epileptic seizures and ADHD that it has been recognised as evidence-based and efficacious (Yucha & Montgomery, 2008; Sherlin et al., 2010; Gevensleben et al., 2013). Neurofeedback is a self-regulation modality that really began in the 1960s and 1970s. It is a form of biofeedback that uses surface sensors on the head and ears to provide real-time information to an individual on the state of their brainwaves.

Neurofeedback training is an operant conditioning technique used to reinforce or inhibit specific brainwaves (Demos, 2005). EEG activity is typically divided into distinctly named frequency bands. Brainwaves that are less than 4 Hz are called delta waves (brainwaves often associated with a slow wave sleep state); 4 to 8 Hz are theta waves (a drowsy/inattentive state); 8 to 12 Hz are alpha waves (a relaxed/wakeful state); and 12 to 30 Hz are beta waves (an active/attentive state).

In 1972, Barry Sterman published a case study that demonstrated a complete cessation of seizures in a woman who successfully learned to increase certain frequencies over the sensorimotor strip using feedback. It was Sterman's work investigating electroencephalographic patterns associated with inhibition in both animals and humans that led to the identification of what is now called the sensorimotor rhythm frequencies (SMR), generally 12-15 in adults and 12-14 in children. These frequencies are called SMR only when they are produced across the sensorimotor strip. The application of SMR training has been central to the development of neurofeedback treatment for seizures and ADHD (Monastra et al., 2005). Sterman has proposed that mechanism of effect of SMR neurofeedback training on attention lies in decreased somatosensory and motor interference in cognitive processing.

In terms of neurofeedback research as it pertains to ADHD, the focus has been primarily on children. The most common electroencephalographic pattern found in this population is an excess of slow wave activity in the frontal regions of the brain, although other patterns have also been identified (Chabot & Serfontein, 1996; Clarke & Barry, 2004; Lansbergen, Arns, van Dongen-Boomsma, Sponk, & Buitelaar, 2011; Loo et al., 2013; Lubar, 1991; Monastra et al., 1999; Ogrim, Kropotov, & Hestad, 2012; Snyder et al., 2008). Successful alterations in brainwaves, and subsequent improvements in ADHD behaviours, have for the most part involved training in frontal, central and midline regions of the brain (Arns, Drinkenburg, & Kenemans, 2012;

Gevensleben et al., 2009; Gevensleben et al., 2013; Kaiser & Othmer, 2000; Lévesque, Beauregard, & Mensour, 2006; Lubar & Shouse, 1976; Monastra, Monastra, & George, 2002; Thompson & Thompson, 1998).

One of the first successful uses of neurofeedback as a treatment was in 1976. Lubar and Shouse (1976) used a training regime that sought to reinforce 12-14 Hz and inhibit 4-7 Hz at the vertex of the brain in an 11 year old presenting with hyperactivity. The training effect was a tripling of SMR levels associated with improved performance in the classroom, as measured by a decrease in out-of-seat behaviour and more school work being completed. In addition, improvements in oppositionality were reported. To ensure that gains were due to the biofeedback, a reversal study design was used and the boy was trained to decrease his SMR activity to baseline levels and increase theta over 38 sessions. A loss of the behavioural improvements followed, but they were regained when the subject once again successfully trained to increase SMR and decrease theta. The study was replicated using one electrode at the vertex of the brain (the international 10/20 site Cz) with four more participants diagnosed with hyperkinesis (Shouse & Lubar, 1979). SMR enhancement became a fundamental protocol in much of subsequent neurofeedback research and continues to be an essential part of neurofeedback training today (Demos, 2005; Russell-Chapin et al., 2013).

As in any emerging treatment, initial inquiries were for the most part on a small scale but results were highly encouraging (Linden, Habib, & Radojevic, 1996; Lubar 1991; Rossiter & LaVaque, 1995; Tansey, 1993). Their success led to case studies and controlled research designs with larger numbers of participants, providing a more rigorous examination of the technique. Positive outcomes were nonetheless maintained and included improved behavioural symptoms and academic performance (Monastra et al., 2002), as well as improvements in a variety of cognitive measures (Kaiser & Othmer, 2000; Fuchs, Birbaumer, Lutzenberger, Gruzelier &

Kaiser 2003). One striking report came from a multi-case study which presented results from 111 patients who consulted at a clinic in Ontario (Thompson & Thompson, 1998). Their findings provided evidence that neurofeedback training with an emphasis on SMR enhancement could lead to an average increase of 12 points on the Wechsler Full Scale Intelligence Quotient. These same researchers have pursued their work with ADHD patients but now report remarkable success with clients diagnosed with Aspergers.

Normalising Brain Profiles

The advances brought on by improved computer analysis of the EEG produced a wave of research in the field of neurometrics. Neurometrics is the quantification of useful measures of the EEG in order to produce objective classifications of the resulting profiles (John et al., 1977). This work brought an important dimension to the practise of neurofeedback. Comparisons of EEG features obtained from patients with specific disorders to values obtained from a population of normal individuals led to the creation of databases that permitted the detection of EEG profiles that deviated from the norm (John, Prichep, Fridman, & Easton, 1988; Thatcher & Lubar, 2009).

With the identification of 'normal' and 'non-normal' profiles within the EEG, clinicians were able to develop a variety of training protocols that were designed, in the case of ADHD for example, to inhibit slow brainwaves and stimulate faster ones in order to 'normalise' brain function. The enhancement of higher levels of beta (anywhere from 12 to 20) was often combined with the inhibition of theta in an attempt to improve symptoms (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Carmody, Radvanski, Wadhwani, Sabo, & Vergara, 2001). SMR enhancement was not always included in these new protocols and a select few even had success with protocols that had no inhibition of theta (Kropotov et al., 2005). The majority however, focused on improvements in the ratio of theta to beta as measured at the vertex (Cz). Based on the hypothesis that children with ADHD could not produce the higher levels of beta, Joel Lubar proposed the

theta/beta ratio as an indicator of the dysfunction (Lubar, 1991). It became the sine qua non of ADHD neurofeedback research and development.

Until recently, three primary brainwave profiles have consistently been seen to appear more frequently in young patients with ADHD, both inattentive and combined, when compared to participants without the diagnosis (Chabot, di Michele, & Prichep, 2005; Clarke & Barry, 2004; McGee, Clarke, Barry, McCarthy & Selikowitz, 2005; Clarke et al., 2011). As mentioned, the majority exhibit cortical slowing in anterior regions. This profile corresponded nicely to a theory proposed in the early 1970's that these children were hypoaroused (Chabot & Serfontein, 1996). This group has included individuals with high levels of frontal theta and frontal alpha and is considered a pattern of 'cortical hypoarousal'. The second most frequent pattern to be observed is one of excessive activity over frontal regions. These patients were believed to have a 'hyperaroused' profile, but a recent investigation of ADHD participants with this profile has shown that despite decreased theta/beta ratios and greater relative beta activity when compared with normally developing participants, they are not actually hyperaroused as measured by skin conductance levels, but can be hypoaroused similarly to those characterised with high theta (Clarke et al., 2013). Furthermore, many of these participants respond to stimulants, supporting the idea of hypoarousal within the central nervous system (Chabot, Orgill, Crawford, Harris, & Serfontein, 1999). A third EEG subtype called the maturational lag profile in children is so named because of the presence of increased anterior delta and theta waves with low beta, which is typical of young children (Chabot et al., 2005). Ambiguity in the analysis of brain profiles stems from the fact that all of the above-mentioned profiles have also been observed in control participants without a diagnosis, albeit to a much lesser degree (Arns, Gunkelman, Breteler, & Spronk, 2008). These are not the only profiles seen in participants with ADHD, who can also exhibit more 'normal' brain patterns, but the majority do manifest clear deviations

neurophysiologically. The advances in the fields of neuroimaging and neurochemistry, as well as in the genetics of brain development, support this contention (Cortese, 2012).

The Theta/Beta Ratio

There was the hope that the EEG would yield a biomarker for ADHD. Many DSM-IV-TR ADHD symptoms are common to other psychiatric disorders, as well as to normal variations in maturity amongst childhood and adolescent behaviours. Rating scales have frequently been used as the basis of an ADHD diagnosis, and although they have been shown to easily identify someone with ADHD symptoms (sensitivity), they have been poor in distinguishing ADHD from other disorders (specificity) (Quintana, Snyder, Purnell, Aponte & Sita, 2007). The many difficulties inherent in the process of diagnosing ADHD have spurred an interest in finding a diagnostic tool that is both sensitive and specific to ADHD. Finding a biological indicator of the disorder that would reduce the number of false positives would be clinically very valuable. Following upon Lubar's work, the theta/beta ratio became a likely candidate.

A study conducted in 1999 sought to establish the theta/beta ratio as a means of accurately identifying children with ADHD (Monastra et al., 1999). The researchers believed they were successful in proving the usefulness of the theta/beta ratio by correctly identifying 86% of the participants with ADHD and 96% of the non-ADHD participants in a combined group of 482 children. Despite the varying clinical presentations of the different subtypes of ADHD, it was believed, perhaps precipitously, that the theta/beta ratio could serve as a tool in the diagnosis of the disorder. This hypothesis appeared to be supported by the many successful treatments based on improving the theta/beta ratio in patients through neurofeedback training (Arns et al., 2009).

Although ultimately the data resulting from subsequent examinations of the ratio has proven equivocal (Lansbergen, Arns, Dongen-Boomsma, Spronk, & Buitelaar, 2011; Liechti et al., 2013; Loo et al., 2013; Ogrim et al., 2012), its initial promise as a neurometric for ADHD led to

numerous inquiries which contributed additional pieces to the puzzle over the last decade. Despite recent FDA approval of a diagnostic tool for ADHD based on the theta/beta ratio, up-to-date research indicates that the difference between the theta/beta ratio of ADHD groups and normal groups has been diminishing over the years (Arns, Connors & Kraemer, 2012). A study published in the same journal reported that the ratio of their normal control group was higher than traditional control groups (Loo et al., 2013). The ratio's capacity therefore to distinguish reliably between the groups is also diminishing. The authors conclude that the theta/beta ratio can no longer be considered a diagnostic measure even though it is still found more often amongst children with ADHD. What does appear to have been confirmed, however, is that the presence of high amplitudes of theta in central and frontal locations are markers for the presence of inattention and executive function disorders, but that like ADHD itself, the heterogeneity of symptoms involved in the diagnosis cannot be represented by one EEG signature alone (Ogrim et al., 2012). Although it remains to be seen, the theta-beta ratio may still qualify as an RdOC (Research Domain Criteria) biomarker, an endophenotype characterizing a treatment-responsive group that cuts across phenomenological diagnostic categories such as ADHD subtypes (Arnold et al., 2013). It has been argued that a low theta/beta ratio should primarily signal to diagnosticians who might use the ratio in the context of an ADHD assessment to investigate more carefully as symptoms are likely to be due to other conditions (Snyder, Rugino, & Stein, 2015),

As the qEEG gains ground as a means of choosing the right treatment for patients, more work is being done to understand the relationship between the EEG pattern and responsiveness to all treatments, not just neurofeedback. An important element that has been re-emphasized, especially in more recent work, is the problem associated with the use of fixed frequency bands in assessing individual patients. Brainwaves are not only identified by the frequency of the wave, but also the morphology of the wave in the EEG. Digital filters of the EEG such as the Fourier Transform,

make assumptions as to the morphology of waves that are artificial and can sometimes lead to ambiguities (Collura, 2014). As a result, when band widths are fixed, unusually high or low frequencies which would be considered a particular type of brainwave such as alpha, are sometimes identified as another variant, for example, theta. Although it is common knowledge that the individual alpha peak frequency can vary in individuals, this element has not been factored into a great deal of the research of the last twenty years. It may also prove to be one of the main reasons neurofeedback research outcomes have varied to the extent they have, in a very similar fashion to medication research outcomes.

Arns et al. (2008) pointed out the importance of establishing the individual alpha peak frequency when assessing for an excess of theta in the front of the brain. By the age of ten, the alpha peak frequency is around 10 hertz. If however, an individual has a slowed alpha peak frequency (below 8.5-9), what is interpreted as a theta excess in the front of the brain might actually be alpha waves intruding frontally. One study that found a significant difference between an ADHD group and a control group based on the theta/beta ratio found the significance disappear when slowed alpha peak frequencies were taken into consideration (Liechti et al., 2013). Given that the sources within the brain of alpha and theta waves are not the same, a misinterpretation of slowed waves could have an effect on the success of the treatment. For example, it has been suggested that alpha is more responsive to a selective serotonin reuptake inhibitor, whereas theta is better addressed with a stimulant (Johnstone, Gunkelman & Lunt, 2005). The qEEG will produce the same misinformation unless it is analysed by an expert with significant experience. Research using qEEGs needs to address this concern in order to draw proper conclusions, so although qEEG-driven neurofeedback is gaining ground as clinical treatment because it avoids the difficulties inherent in applying a single treatment to a heterogenous condition such as ADHD (Arns et al., 2012b), the research in this area is in its

infancy. Most research designs are not qEEG-based and continue to use a single protocol that has been shown to be clinically useful in treating a diagnosed condition.

These latest developments will alter the entire approach of neurofeedback training as more research into the complex sources of dysfunctional neuroelectrical patterns emerges. Most important for this study, however is the choice between two recognized "attention" protocols; the theta/beta ratio training, a mainstay of neurofeedback, and SMR training. Interestingly, the ubiquitous SMR enhancement protocol is often recommended as a standby when qEEG deviations are unclear, or when the qEEG is not used to direct protocol choice (Arns et al., 2012b).

Adult ADHD EEG Profiles

Most of the previous discussion has centred on children as they have been the focus of much of the research into the use of neurofeedback for ADHD. The initial two main patterns of frontal slow frequencies, and a smaller percentage with an excess of fast frequencies, persist in adolescents and adults as well although results across studies can vary (Clarke et al., 2008; Keune et al., 2011; Liechti et al., 2013; White, Hutchens, & Lubar, 2005). The pattern most associated with inattention has been termed 'thalpha' because it encompasses slow frequencies from 6-10 Hz which include theta and alpha brainwaves (Thompson & Thompson, 2003). These authors have also identified a group of adults who exhibit attention problems because of their tendency to ruminate rather than 'drift off.' They present with high levels of fast frequencies, often within the 22-35 Hz range (beta frequencies nicknamed by the Thompson's as busy-brain frequencies), but the main profile for adults appears to be the 'thalpha' pattern. A study comparing 34 adults with ADHD and 34 control participants confirmed these findings (Koehler et al., 2009). The ADHD patients showed a significant increase of absolute power density in alpha and theta bands.

Another study found a correlation between increased beta levels and rating-scale measures of attention problems and metacognition in adults (Ogrim et al., 2012).

.**Medication Control Studies**

Brain profiles and their relationship to behaviour patterns are pertinent not only to the field of EEG biofeedback. The frequent presence of divergent brain-based patterns, even amongst groups with similar behavioural problems, has been proposed as an explanation as to why the outcomes to methylphenidate and amphetamines can be unpredictable (Gunkelman, & Johnstone, 2005). It appears that the effectiveness of medication can be improved upon if the choice is based on the neurophysiological profile rather than on a set of behavioural symptoms, as is current practise (Collura, 2014). Decades of pharmacological studies have nonetheless provided significant outcomes that establish a minimum that must be met by newer treatments. It was inevitable that stimulants serve as an active control in research designed to assess the effectiveness of neurofeedback as a treatment option for ADHD

Seven clinical studies have compared neurofeedback to either a medication treatment group, or a multi-modal treatment group that included medication (Duric, Assmus, Gundersen & Elden, 2011; Fuchs et al., 2003; Monastra et al., 2002; Nazari, Querne, De Broca & Berquin, 2011; Meisel, Garcia-Banda, Cardo & Moreno, 2013; Rossiter & LaVaque, 1995; Rossiter, 2004b). Not all of these studies were random-controlled trials although two of the most recent assigned participants randomly to the treatment conditions (Duric et al., 2011; Meisel et al., 2013). In arguing the case against randomisation to a control treatment with medication, the assertion is that parents may have strong viewpoints for or against medication. This may explain why one of the RCT's mentioned above had one third of their patients drop out before the study could begin (Duric et al., 2011).

A year-long multi-modal study conducted in a school setting combined known interventions for ADHD including medication (Ritalin), parent training/counselling, a school program and neurofeedback (Monastra et al., 2002). All of the 100 children enrolled in the study participated in the medication, parent counselling and school support (CCC), and all 100 were assessed to ensure that they exhibited a high theta/beta ratio indicating cortical hypoarousal. The neurofeedback treatment was added on for 51 of the children, who received an average 34 weekly sessions of the Lubar theta/beta protocol (CCC+B). The children were reassessed twice at the end of the year using rating scales for teachers and parents, and a computerised test of attention. The author concluded that the short-acting Ritalin used probably accounted for the results of the CCC group which indicated that despite improvements over the year, they were still considered impaired when assessed by teachers and parents on a behaviour rating scale. The neurofeedback group did not exhibit the equivalent impaired behaviour although they received the same dosage of Ritalin as the CCC group. A further assessment was performed following a medication wash out of one week. Whereas all of the CCC group's measures returned to pre-treatment baselines, the CCC+B group maintained their improvements. Effect sizes in this study were large for combined neurofeedback, parental training, initial medication and school intervention treatment (ES=2.22 for inattention; 1.22 for hyperactivity).

A German study, also conducted in a clinical setting, gave parents the choice of treatment with medication or with neurofeedback (Fuchs et al., 2003). The authors argued that this option would enhance treatment compliance although they recognised that they were therefore not able to control for non-specific factors affecting the outcomes. They reported that the 22 children who were assigned to the 36 sessions of neurofeedback completed the treatment, whereas one of the 12 children who chose medication was unable to continue due to side-effects. Both groups had

significant improvements on parental rating scales of behaviour as well as two tests of attention, but neither surpassed the other.

A replication of one of the first comparison studies between neurofeedback and stimulants (LaVaque & Rossiter, 1995) was conducted with a larger sample size (62 children), improved matching of the treatment and control group, and better statistical analysis (Rossiter, 2004b). (Participants chose whether or not to be part of the medication treatment group.) The neurofeedback group's post-treatment scores on the Behavior Assessment System Children (BASC) and Brown Attention Deficit Disorder (BADD) fell within the average, non-impaired range after the training. The BASC is a report scale that examines different dimensions of psychopathology in children (hyperactivity; attention; externalising; internalizing) and the BADD scale is a checklist of primarily executive function symptoms. Only the internalizing scale was in the average range prior to the treatment. Both treatment groups exhibited equivalent improvements on a continuous performance test. The neurofeedback used by Rossiter in this study targeted the left hemisphere (at C3) for children with inattention and daydreaming, the right hemishphere (at C4) for those with impulsivity and distractibility, or both for a combination of the two dimensions.

One of the few studies to randomise patients to one of three treatment groups (a neurofeedback group, a methylphenidate group and a neurofeedback with methylphenidate combined group) reported significant improvements on a parent rating scale for the 30 or so children in each group, with no significant differences between the groups (Duric et al., 2011). The neurofeedback group received 30 sessions of theta inhibition and beta enhancement at CZ. Finally, one of the most recent studies comparing medication and neurofeedback also randomised participants to either a methylphenidate group or a theta/beta neurofeedback group (Meisel et al., 2013). (This study also had to contend with participants dropping out of the study following randomisation due to a

preference for a specific treatment). Pre-post results showed improvements in both groups on certain measures (symptom scales and a parental impairment scale), although only the neurofeedback group showed improvement on teacher rated changes in academic performance. Effect sizes for the pharmacological group tended to be larger. Treatment in the pharmacological group, as well as improvements, were maintained at two and six month follow-ups, whereas 33% of the neurofeedback group were shown to have maintained improvements without continued neurofeedback treatment. It should be noted that eight of the initial twelve neurofeedback participants eventually resorted to medication in the follow-up period. The investigators excluded those children in the analysis, but this is an important consideration.

A tentative conclusion is that when there is no pre-selection, positive outcomes appear to be similar in both treatment approaches. But when patients were pre-selected for a specific EEG pattern that the treatment protocol then addressed specifically, neurofeedback outcomes surpassed those of medication (Monastra et al., 2002). Ultimately, the variety of brain profiles included in the typical cohort of ADHD patients probably explains why neither medication nor neurofeedback (when training is not specific to a profile) have predictable outcomes. Perhaps information on the direct effects of ADHD medication on the EEG will add to the discussion.

Unfortunately, a review of studies exploring that very question only complicates matters, as it reveals many inconsistencies and contradictions in the research. Some have reported the normalisation of the hypoaroused or frontal slow profile with stimulants (Clarke et al., 2003) while others have not (Arns et al., 2008; Chabot et al., 1999; Lubar, Swartwood, Swartwood, & Timmerman, 1995). Yet the ‘busy brain’ variant with excessive beta can also respond to stimulants. There is also evidence that anticonvulsants have been found to improve symptoms in some ADHD clients (Gunkelman & Johnstone, 2005). Arns et al. (2008) report that amphetamines appear to be most effective for cases of high frontal alpha (slowing in the front of

the brain) particularly when the alpha peak frequency is low. Taken altogether, these findings would suggest that although an examination of the EEG may predict responsiveness to medication, it might prove to be even more useful in predicting whether or not neurofeedback would be the most effective form of treatment for some clients. Much more research is needed in this area, but some of the knowledge garnered to date is helping resolve questions that have long been unanswered.

Recent Random Controlled Trials

As mentioned, one of the major criticisms of the research in the field has been the lack of randomised controlled studies (RCT) (Loo & Barkley, 2005). Although there had been several controlled studies prior to 2005, there were drawbacks associated with a number of them, such as small sample size or what were considered subjective outcome measures. Since that time there has been a surge of renewed scientific study relating to neurofeedback as a treatment for ADHD. A few of the more significant studies will be briefly reviewed.

One of the first RCT's with a major impact on the field of neurofeedback research was a study that featured functional magnetic resonance imaging (fMRI) changes as an outcome measure (Lévesque, Beauregard, & Mensour, 2006). Based on the evidence that the functioning of the anterior cingulate cortex is abnormal for those with ADHD during tasks involving selective attention, these researchers investigated whether neurofeedback would effect change in the pre and post scans of fifteen unmedicated children performing a Stroop task. Twenty sessions with Lubar's SMR/Theta protocol (enhancing SMR 12-15 hz and inhibiting theta 4-7 hz) over the vertex were followed by twenty sessions of theta/beta training (inhibiting theta 4-7 hz and enhancing beta 15-18 hz). Although the study had small numbers of participants, the neuropsychological (digit span and a continuous performance test) and behavioural measures significantly improved and provided solid empirical support for the neurofeedback treatment. The

activation of the right anterior cingulate cortex revealed by this research suggested that this form of training could effectively normalize brain activity in these patients. Five more children had been assigned to a no treatment control group, but the lack of a sham treatment has been a criticism of the study. It is however generally recognized that a placebo effect would probably not have produced activation in the brain area under investigation.

Three recent RCT's from Germany employed intensive active control groups that involved equivalent amounts of time in treatment as the neurofeedback. A well-designed study published in the *Journal of Child Psychology and Psychiatry* (Gevensleben et al., 2009) has been considered the most solid methodological study to date since it had a large sample size (94 participants), as well as a control group that can be considered a credible sham control group. Forty-six children randomly assigned to the experimental group were offered either theta/beta or slow cortical potential training. Over the course of 36 sessions, they either trained to reduce theta activity (4-6 hertz) and increase beta activity (13-20 hertz) or they trained to increase/decrease slow cortical potentials aimed to increase central-midline alpha activity. The other children (26) received computerised attention skills training designed to improve vigilance and reactivity. Parents and teachers were blind as to the particular training the child received. There were significant improvements in the experimental group of behaviour rating scales by parents and teachers for inattention and hyperactivity/impulsivity even though there were not equivalent changes in the EEG. For example, despite reductions in theta activity over the course of the treatment, the reductions were not significant. All of the children were directed to think about the strategies they were developing and to practise the skills outside of the clinical setting. Interestingly, the author has stipulated that these transfer skills are essential to the generalisation of the effect of the treatment, and that without them the significant benefit of the training (26% improvement in the primary outcome measure) is lessened.

A pilot study conducted in the same year described neurofeedback as a "behavioural technique" developed to improve the core symptoms of ADHD by modifying neurophysiologic parameters (Holtmann et al., 2009). Thirty-four children with ADHD were randomly assigned to a neurofeedback intervention or to a computer brain-training treatment. Parent rating scales and a stop signal paradigm (a measure of response inhibition) were the outcome measures. Interestingly, the parent rating scales showed no significant difference between the groups, whereas the cognitive performance measure found that the neurofeedback group had normalised response inhibition. A common criticism of neurofeedback has been that parents can be intimidated by the high-tech nature of the treatment and exaggerate any benefits achieved. In this study, this purported effect was not apparent. This concern can best be addressed by choosing comparison treatments that are equally high-tech in nature. The third German RCT used a continuous performance test and a paper-and-pencil short-term selective attention test, as well as parent and teacher rating scales, to compare a neurofeedback group to another biofeedback modality, electromyography (EMG) for children considered hyperkinetic. This biofeedback was considered similar enough to the neurofeedback to control for unspecific effects such as parental engagement and motivational effects on the participants. Results indicated that both groups showed improvements, particularly on the paper-and-pencil tests, but only the neurofeedback group improved significantly in three areas; the commission errors which are a sensitive measure of impulsivity and inattention; the parental rating scale for inattention; and the teacher rating scale for impulsivity (Bakhshayesh, Hansch, Wychkon, Rezi, & Esser (2011).

Sham Control in Neurofeedback

Sham controlled studies have proven problematic for neurofeedback research. Because of this issue, the mainstream community has been hesitant to accept neurofeedback as a treatment option except when medication proves undesirable. The specific mechanisms involved in the benefits

seen in large numbers of neurofeedback studies cannot be considered actual brain-based alterations of neuronal functioning rather than placebo effects or changes due to other non-specific variables. Because of the limitations in terms of research design, most neurofeedback studies are not included in reviews of the evidence-base for the approach. A 2014 review of psychosocial treatments for children and adolescents with ADHD reviewed only one study (the 2009 Gevensleben study) and rated neurofeedback as "possibly efficacious" (Evans, Owens, & Bunford, 2014). Unfortunately, it is difficult to design an equivalent feedback that is inert and that would not be easily recognised by participant and therapist alike. This situation could lead to indifference on the part of the subject with a skewing of the results. Neurofeedback as an operant conditioning technique does not require effort on the part of the participants, but there must be an element of volition or engagement (Collura, 2014). Neurotherapists have argued that methodological and ethical limitations prevent them from incorporating a sham treatment group to pinpoint the mechanism of efficacy in neurofeedback (Rossiter, 2004a). When one considers the significant time commitment involved in such a treatment, it is difficult to rationalize asking people to enroll in studies where one of the conditions is a placebo. Children with ADHD are often already lagging behind their peers in several aspects of their development. To expose them to an inert treatment for a protracted period of time and risk aggravating the lag is problematic.

Several attempts have been made to overcome the current limitations of sham treatments, but most have been considered inconclusive, whether they showed neurofeedback to be effective or not (Gevensleben et al., 2013). The criticisms of these studies have focused primarily on methodological limitations such as the use of non-standard protocols, or very small numbers of participants (Logemann, Lansbergen, Van Os, Bocker, & Kenemans, 2010; Perreau-Linck, Lessard, Lévesque & Beauregard, 2010). A novel sham treatment used in a recent doctoral thesis may very well provide a solution for researchers (Moreau, 2012). The two-part study initially

used a wait-list condition while fifteen children completed neurofeedback training for ADHD. Their recorded brainwaves were then subsequently used as the sham feedback for a control group in a second intervention with 31 children. A technician who was blind to the use of the substituted brainwaves, and trained in neurofeedback specifically for this experiment, did the training with the children. Improvements were identified in both studies on parent-rating scales, and for the second study, on neuropsychological measures of working memory and verbal comprehension.

Currently, there is a joint effort to design and conduct a massive sham-controlled study which it is hoped will help identify the specific mechanisms involved (Arnold et al., 2013). For the time being, it can be concluded that neurofeedback is a valid *psychological* treatment based on the principal of operant conditioning with as yet unidentified mechanisms of action (Gevensleben et al., 2013; Simkin, Thatcher, & Lubar, 2014).

Neurofeedback and Substance Use Disorders

Another main area of research in neurofeedback has been its application in addiction therapies. The main type of training in this domain has been the alpha-theta brainwave feedback protocol developed by Peniston and Kulkosky (1989) for the treatment of chronic treatment resistant alcoholics. Often called “deep states training”, the goal of alpha-theta therapy is to enable the person to enter into a profound, liminal state between sleeping and waking and maintain the effect for a protracted period of time. In this state, the mind can be directed or conditioned more easily because of a purported easing of psychological defence systems (Soutar & Longo, 2011). Gene Peniston developed this approach by combining two training techniques, each of which targeted specific brainwaves. Alpha training can be used to deepen awareness while at the same time, increasing physical relaxation, whereas theta training brings on the border state between sleeping and waking. Peniston used this combination as one component of a treatment for alcoholics within

a residential program that also utilised visualisations, autogenics and rhythmic breathing alongside more traditional therapy.

Although numerous studies have confirmed reports that the alpha-theta protocol is an efficacious co-treatment for alcohol, its success as a treatment for other abuse substances such as cocaine, marijuana and stimulants has been less clear cut (Trudeau, 2005). In an attempt to potentiate alpha-theta therapy in these populations, the treatment was eventually modified to include protocols normally used for other issues. SMR training, in particular, was explored to see whether its inclusion could improve treatment outcomes given the success seen in ADHD and epilepsy, as well as its reputation to produce calm, insight-oriented improvements in participants (Gruzelier & Egner, 2005). The hypothesis was that protocols that included SMR enhancement would be a potential adjunct treatment for clients who may have altered their brain functioning through drug use (Trudeau, Sokhadze, & Cannon, 2009).

One such protocol is the so-called betaSMR protocol, or sensorimotor-beta training, which is designed to enhance SMR frequencies (12-15) on the right side of the brain, and higher beta frequencies (15-18) on the left side of the brain. A research study with over 1000 participants showed that sensorimotor-beta training led to significant improvement in attentiveness, impulse control, and response variability on a continuous performance test (Kaiser & Othmer, 2000). In this particular study, each side of the brain, at C3 and C4, was treated one after the other. Success has also been reported when the enhancement of the different frequencies is done simultaneously - a treatment made possible by the development of amplifiers with more than one channel (Putman, Othmer, Othmer, & Pollock, 2008).

The main adaptation, therefore, to the alpha-theta treatment for addictions with stimulants was to include betaSMR training. This is known as the Scott-Kaiser modification of the Peniston Protocol (Scott et al., 2005). These researchers tested their modification by training participants from a

mixed substance abusing population using a betaSMR protocol until their attention scores on a continuous performance test normalised. They reported an average of 13 sessions in order to do so. The betaSMR training was then followed up by the alpha-theta protocol as part of a multi-faceted treatment programme. In a randomised controlled study of the modified protocol in combination with standard therapy, 77% of those in the experimental group were abstinent at 12 months compared to 44% of the control group which had received no neurofeedback (Scott et al., 2005).

The SMR Protocol

Although SMR training has been a mainstay of neurofeedback since its elaboration by Sterman in the 70's, there has been a recent resurgence in interest in order to explain why voluntary production of the sensory motor rhythm is so effective for a variety of disorders including epilepsy, ADHD, Tourettes, fibromyalgia, sleep, memory, and possibly others such as Aspergers and mood disorders (Benvenuti, Buodo, Leone & Palomba, 2011; Gruzelier, 2014; Hammer, Colbert, Brown, & Ilioi, 2011; Kayiran, Durson, Dursun, Ermutlu, & Karamürsel, 2010; Thompson & Thompson, 2009b; Vernon et al., 2003). In fact, SMR training is the fallback protocol when an assessment of brainwaves does not reveal a profile associated with specific difficulties, or when there are no identifiable areas or hot spots outside of normal functioning (Arns et al., 2012b). A study using functional magnetic resonance imaging before and after forty SMR enhancement training sessions showed evidence that the neurofeedback had consolidated the Default Mode Network in twelve children diagnosed with ADHD (Russell-Chapin et al., 2013). The results confirmed the findings of the Lévesque et al. (2006) who had used an SMR/Theta training protocol. Arns and Kenemans (2012) have proposed a disturbed vigilance model for the impact of SMR work as related to certain subtypes of ADHD. They hypothesize that SMR training, as well as slow cortical potential neurofeedback have an impact on the sleep spindle

circuitry, thereby stabilizing vigilance. This model ties in nicely with Sterman's work examining the sleep spindle activity of cats.

It has always been assumed that it is the *enhancement* of SMR that produces therapeutic effects. As such, it has been proposed that therapeutic benefits can only be truly obtained when there is a concomitant increase in scores and that this should be the basis for the measure of effectiveness of neurofeedback studies. For SMR enhancement in particular, this is a complex issue. Although the goal of most SMR training is generally a significant increase in SMR scores, behavioural improvements can occur without it, and vice versa. Several authors have noted that despite improvements in targeted behaviours and abilities, and despite within session increases in SMR scores, there was no corresponding increase in the SMR score across sessions. This is perhaps because increases in SMR can at times be a very slow process. Behaviour changes may pre-cede significant amplitude increases as control over the SMR response is developed. Using healthy participants, the SMR score was found to rise significantly only at the very last training period (Dopplemayer & Weber, 2011). At times, the score has even been found to be lower at the end of a training period than at the beginning. Arns et al. (2012b) reported a decreased SMR score after more than twenty sessions during which ADHD participants tried to increase their SMR, yet there were indications of a normalisation of underlying neural circuitry related to stimulus discrimination and attention/memory updating and an improvement in behavioural outcome measures., or even to decrease initially and as participants became more skilled, to eventually increase. Kleinnijenhuis, Arns, Spronk, Breteler and Duysens (2008) found a relationship between the slow cortical potential and SMR whether the subject was working at increasing or decreasing SMR. Vachon-Presseau, Achim and Benoit-Lajoie (2009) found that tasks requiring increased attention actually lowered SMR. Other researchers noticed that when SMR was increased at Cz (while a subject with Tourettes was also trying to decrease theta) SMR decreased at C4 initially,

eventually to increase but without exceeding pre-training levels despite significant changes in symptoms (Benvenuti et al., 2011).

In summary, the changes in SMR amplitude do not appear to always correlate with changes in behaviour. Enhancement can be very slow, or can occur in as little as eight sessions (Vernon et al., 2003). It has been suggested that like slow cortical potential training, it is the improvement in control of the elicitation of an SMR bursting response, whether scores increase or decrease, that leads to therapeutic change, and that participants develop their own individual strategies for doing so (Arns et al., 2012b). There is much to be understood in terms of the mechanism of change in SMR neurofeedback, not unlike other therapeutic modalities, such as psychotherapy, that have been used prominently for decades.

Research Goals

In conclusion, although neurofeedback to address attention problems has already been used successfully in the context of substance use disorders (the Scott-Kaiser modification protocol in particular) there is little research on neurofeedback in a smoking cessation context for this group of patients. Given that they are at increased risk for significant health complications, any potential therapy to improve smokers` ability to stop smoking would be very valuable, especially one that could be easily incorporated into a clinical practice. Most neurofeedback addiction research has included multiple variables (e.g., residential settings; other biofeedbacks; the alpha-theta protocol combined with guided visualisation). The investigation of an “attention protocol” such as the betaSMR protocol as a potentiator of a known smoking cessation treatment in the context of a clinical setting would be useful. Stimulants prescribed for attention problems in addition to nicotine replacement therapies have been shown to have an impact on cessation attempts, although inconsistent results may be confounded by increased adverse effects of the medication, as well as

other less well understood factors. As such, these elements support the exploration of the potential efficacy of a betaSMR neurofeedback treatment for individuals with attention deficits who are struggling unsuccessfully to quit smoking. Improving attention through a self-regulation biofeedback treatment such as the betaSMR protocol may place smokers with ADHD on an equal footing with other smokers who benefit from the use of a nicotine replacement therapy to diminish their dependence on smoking cigarettes to acquire the nicotine their brain has become accustomed to, and to control withdrawal symptoms that undermine their cessation attempts. As the neurofeedback works to improve performance on a measure of attention, participants with ADHD who are already using an NRT unsuccessfully may find their ability to reduce their smoking may improve.

Study Objectives

The primary objective of this study was to investigate the impact of neurofeedback on a conventional smoking cessation treatment for adults with ADHD and nicotine dependence. More specifically, the study assessed the effect of a betaSMR treatment protocol on the ability of smokers with ADHD to refrain from smoking while using a nicotine patch. The contention put forward was that improvement in attention following the neurofeedback treatment would gradually help to reduce dependency and withdrawal symptoms and lead to eventual abstinence.

Hypothesis

It was hypothesized that a neurofeedback treatment would significantly improve attention as measured by a continuous performance test, in smokers with ADHD who were unable to quit despite the use of a nicotine patch, thereby reducing dependency and withdrawal symptoms as measured by a scale evaluating six dimensions of withdrawal, to result in a decrease in nicotine dependence as measured by a scale derived from the DSM-IV-TR definition of nicotine dependence.

Methods

Design

A single case experimental design was used to evaluate the effects of the neurofeedback treatment (Kazdin, 1978). In order to maximise internal validity, a multiple baseline across participants design (MBD) was chosen (Kratochville & Levin, 2010). A single transition from baseline to treatment was instituted given the impossibility of negating the effects of the treatment in a subsequent withdrawal phase. This design is relevant to practitioners in clinical settings. Ethical considerations required a non-concurrent start to each baseline phase. It would have been detrimental to the efforts of the participants struggling to quit smoking to require them to wait until sufficient participants were recruited in order to start them all concurrently. Furthermore, some participants were eager to begin the experimental treatment as they were already unsuccessful with the NRT. It was decided to respect fixed start times rather than use a response-guided introduction of the treatment phase. Participants were randomly assigned to different baseline lengths as soon as the assessment process was completed. Ultimately, the pre-established baseline lengths of the design (12, 10, 8 and 6 days) were not strictly adhered to due to participants changing their availabilities to begin treatment. Actual baselines were 20, 10, 8 and 7 days. During that period, and for the duration of the treatment, participants continued to use the nicotine patch as prescribed to them. The introduction of the treatment in a staggered fashion across the participants was intended to minimize the impact of external factors on the results. As such, a causal relationship can eventually be established in the targeted behaviour following introduction of the neurofeedback treatment. According to Kazdin (1978), confident conclusions can be drawn about the treatment effectiveness using an MBD design when at least three participants are used. Four participants recruited from a bilingual suburb west of Montreal were enrolled in the study and completed the treatment. The treatment phase of the study ended when participants had significantly improved a measure of attention that was tracked throughout the study (after 12 and

13 sessions of neurofeedback). (For the study timelines see Appendix 1). The initial measure of nicotine dependence was repeated ten weeks following the termination of treatment, as well as an evaluation of smoking abstinence as this was the ultimate goal of a smoking cessation treatment.

Screening Measures

FTND: The Fagerström Test of Nicotine Dependence. The FTND (see Appendix 2) is the most widely known measure of nicotine dependence and is most utilized by researchers. The FTND quantifies dependence using six questions that yield a score from 0 to 10 **(**Heatherton, Kozlowski, Frecker &, Fagerström, 1991). It classifies smokers as very low dependence (score 0-2), low dependence (score 3-4), moderate dependence (score 5), high dependence (score 6-7) and very high dependence (score 8-10). The first question (time to first cigarette in the morning) is considered a valid indicator of nicotine dependence. This scale also taps into behaviours associated with difficulty maintaining abstinence due to withdrawal symptoms. The internal reliability coefficient (Cronbach's alpha) is *0.68* for the FTND with a test-retest reliability ranging from *0.67 to 0.87* (Meneses-Gaya, Zuardi, Loureiro, & de Souza Crippa, 2009). As a screening measure to identify moderate to heavy nicotine dependence, an FTND score of equal to or greater than ≥ 5 is recommended, for which the FTND score and saliva cotinine correlation is *0.45* (Huang, Lin & Wang, 2005). In a psychiatric population, convergent validity for total FTND scores correlated *0.38* with milligrams of nicotine per day (Buckley et al., 2005). The scale was chosen in part because participants were potentially French or English and has been adapted and validated in French (Etter, Le Houezec, & Perneger, 1999).

ASRS v1.1: Adult Self-Report Scale (World Health Organisation). The 6-item questionnaire (the first 6 questions of the 18-item scale) was used as a telephone screening tool for the study (see Appendix 3). It has been found that the six first questions are most predictive of the disorder (Kessler et al., 2007). The 18-item screener (completed with the other assessment scales) was

constructed using the DSM-IV-TR symptoms for ADHD. The ASRS v1.1 has a test-retest reliability of *0.58 to 0.70* and an internal consistency coefficient of *0.63 to 0.73* (Kessler et al., 2007). The overall positive predictive value of the ASRS was *0.26* (95% CI: 0.22–0.30), the negative predictive value was *0.97* (Van de Glind et al., 2014). The French version of the scale was adapted and validated in 2009 (Caci, Oliveri, & Dollet, 2009).

Evaluation Measures

CADDRA ADHD Assessment Toolkit (CAAT) - 3rd edition. The Canadian Attention Deficit Disorder Resource Alliance (CADDRA, 2011) is an assessment package for ADHD developed by a multidisciplinary team of Canadian experts. The package is made up of guidelines designed to help in the diagnosis of ADHD across the lifespan. CAADRA is careful to point out that these tools are not diagnostic. They provide important measures of the symptoms that can help identify attention disorders but it is the clinical interview that is the basis of a formal diagnosis. The following scales and questionnaires from the toolkit (see Appendix 4) were used to obtain descriptive information from the participants: the Weiss Symptom Record (WSR) and the Weiss Functional Impairment Rating Scale-Self Report (WFIRS-S) and the Weiss Functional Impairment Rating Scale –Parent Report (WFIRS-P) whenever possible. Otherwise, participants were asked to complete the Wender Utah Rating Scale (WURS) (Appendix 5) in order to establish whether the attention problems dated back to childhood. The WSR is a clinical screening questionnaire based on the DSM-IV-TR criteria. It collects information using 18 subscales about Axis I and Axis II psychiatric disorders in any age group and from any informant. The questionnaire was filled out by the participants to evaluate clinical information on possible co-morbidities. It is not a psychometrically validated instrument but is a clinical record of the DSM-IV-TR criteria for various disorders. The WFIRS-S evaluates the adult's capacity to function in the different areas of daily life and the impact of the behavior. It is a questionnaire

with 50 items grouped in various scales that include the family, work, academic skills, self-concept, life skills, social activities and risky activities, which include inappropriate behaviors related to driving, police, drugs and sex. The scores on the items range from 0 to 3. For clinical purposes, a mean score >1 on some of the domains (except risky behaviors, which is 0.5) indicates a significant dysfunction. The scale has good psychometric properties, with a Cronbach's alpha > 0.9 overall, and subscale domain Cronbach's alphas ranging from 0.75-0.93 (Epstein & Weiss, 2012).

IVA+Plus: Integrated Visual and Auditory Continuous Performance Test Plus. The IVA+Plus (see Appendix 6 for a sample report) is a computerized, cognitive assessment that differs from other continuous performance tests in that it was designed to include both auditory and visual measures in a standardised and individually administered instrument **(**Sandford & Turner, 2000). Using a mouse, the participant is asked to indicate when hearing or seeing a number '1' and to refrain from responding should the stimulus be a number '2'. The 17 minute test measures errors of commission and errors of omission and begins with a brief practice to ensure that the directions are well understood. The main test lasts about 13 minutes during which a total of 500 trials lasting approximately 1.5 seconds each are recorded and ends with a cool-down period. The scores to be tracked in this study will be the Auditory Sustained Attention Quotient and the Visual Sustained Attention Quotient. These are global scores resulting from an analysis of the following scales: Acuity, Dependability, Elasticity, Reliability, Steadiness and Swiftness. They are standard scores and the descriptive categories are: Exceptional 130 and above; Superior 120–129; Above Average 110 – 119; Average 90 – 109; Slightly Impaired 85 – 89; Mildly Impaired 80 – 84; Mildly to Moderately Impaired 76 – 79; Moderately Impaired 72 – 75; Moderately to Severely Impaired 68 – 71; Severely Impaired 61 – 67; Extremely impaired $\leq$ 60. This CPT was part of the initial evaluation of attention in the selection of participants, but

also served as an objective weekly measure of the status of attention throughout the study. When attention normalised, i.e., when at least one of the scores that were monitored was in the average or mildly impaired range, treatment was halted. The test-retest reliability ranges from *0.66 to 0.75* for inattention scores and *0.37 to 0.41* for hyperactivity/impulsivity scores (a four week interval). Reliability and validity was established using a norming sample of individuals from 6 to 70 years of age. In a more recent study, the IVA+Plus correctly identified clinician diagnosed ADHD children 92.3% of the time (Arble, Kuentzel, & Barnett, 2014). Because of the simultaneous assessment within two sensory modalities, this CPT has become popular as a measure for various clinical investigations, both pediatric (Tinius, 2003) and adult (Corbett & Constantine, 2006; Quinn, 2003).

Outcome Measures

CDS-5/CDS-12: Cigarette Dependence Scale. The CDS-12 (and ultimately its subscale the CDS-5) was the primary independent measure of the study (see Appendix 7) and was completed daily by the participants (Etter, LeHouezec, & Perneger, 2003). This scale was selected because participants were potentially French or English speaking, and this instrument was initially developed and validated in French, and then validated in English. The CDS-12 has 12 items that measure core constructs of cigarette dependence according to the DSM-IV-TR and the International Classification of Disease 10th revision (World Health Organization, 1992). The CDS-5, considered the short version of the CDS-12, is composed of the first five of the 12 items from the CDS-12. Each item yields a score from one to five, e.g., "for you, quitting smoking would be" 1= very easy, and 5 = impossible. The cumulated CDS-5 scores yield a measure of dependence ranging from 5 (low dependence) to 25 (high dependence). For the CDS-12, a score of 25 or less indicates a low dependence; between 25 and 44 a moderate dependence and $\geq$ 44 a strong dependence. The average score of the 3009 smokers from France, Switzerland, Belgium and

Canada in the original study validating the scale was 44 (Etter et al., 2003). The CDS-12 has good psychometric properties with a Cronbach alpha of *.084* and a test-retest of *0.83*. The instrument's scores are associated with the strength of the urge to smoke during the last quit attempt ($R^2 \geq 0.25$), and with saliva cotinine ($R^2 \geq 0.17$) (Etter et al., 2003). The CDS-5 is slightly more correlated with cotinine levels in smokers than the CDS-12 (Sato, Sato, Nozawa, & Sugimura, 2012).

CWS-21: Cigarette Withdrawal Scale. The daily measure of withdrawal symptoms was tracked by the CWS-21 (see Appendix 8), a 21-item self-administered scale that evaluates the following six dimensions of a withdrawal syndrome: depression/anxiety; craving; irritability; appetite/weight-gain; insomnias; concentration problems. Each item, e.g. "I would like to hold a cigarette between my fingers", generates a score from one to five reflecting 1 = totally disagree, or 5 = fully agree. The first three dimensions (depression/anxiety; craving; irritability) give scores from 5 to 20 each. The last three (appetite; insomnia; concentration) give scores from 3 to 15 each. The total possible score ranges therefore from 24 to 105. This scale was designed specifically with smoking and smoking cessation research in mind and reflects the symptoms of the DSM-IV-TR and ICD-10. It was developed and validated initially in French (Etter, 2005), then validated in English (Etter & Hughes, 2006). Internal consistency measures (Cronbach's alpha) are between *0.83 and 0.96* and the test-retest ranges from *0.60 to 0.71*. The predictive validity of the craving subscale of the CWS-21, reflecting relapse on day 14 following a quit attempt, (area under ROC curve) = *0.63* (.55-.071) with a CI of 95% CI (Etter & Hughes, 2006).

Participants

Six participants, all women residing in the region of the West Island of Montreal, were recruited for the study, but only four agreed to participate following the assessment because scheduling difficulties (VB, CR, JW, and MT). Each was bilingual, but all identified English as their mother

tongue. Two of the participants had previously been diagnosed with ADHD; one as a teenager in the ninth grade by a local psychologist, and the other as an adult in her thirties by a psychiatrist well-known for her work with ADHD. A third subject was the mother of two children diagnosed with ADHD who felt she had similar issues. Finally, the fourth participant was a nurse in one of the medical offices approached for recruitment who, upon completing the screening instrument herself, felt she had a likely explanation for her difficulties in quitting smoking after many years of trying on and off the patch. Two of the participants (MT and JW) were normally heavy smokers when not trying to quit, smoking more than 30 cigarettes a day, whereas the other two smoked moderately, from 15 to 25 cigarettes per day. At the time of recruitment, all of them had reduced their smoking by using a patch but had resumed smoking daily although to lesser amounts. Because of their continued smoking, each one planned on continuing the patch for a time. As participants were recruited, they were assigned to a baseline length and began the intervention in the following order; CR, JW, VB and MT. The treatment phase of the study spanned the final four months of 2012 and the first two months of 2013. A brief description of each participant, their initial screening and attention scores, along with their motivation for joining the study, ensues.

Participant A (VB). Participant A was a 25 year old who worked as a hairdresser. She had been diagnosed with ADHD, predominantly inattentive type by a psychologist in Grade 9. Her initial scores on the screening instruments were: FTND = 5 or moderately dependent; ASRS-6 = five items endorsed with sufficient severity. At the time of the assessment, her CPT scores placed her in the extremely impaired range (IVA+Plus = 12 for sustained auditory attention and 14 for sustained visual attention). Her WSR self-report results (ADHD section) were three on nine symptoms for inattention and four on nine symptoms for hyperactivity/impulsivity). Other symptoms endorsed on the WSR were an inability to relax, sleeping difficulties and past learning difficulties. Other than smoking (endorsed as very much a problem), her WFIRS-P report

confirmed long-standing issues with the family, school, sleep and smoking. (VB never handed in her own WFIRS-S or ASRS-18 forms, promising repeatedly to bring them in, but always forgetting to do so). She had tried many times to quit smoking and found the habit repugnant, but although she could stop for a brief period, she would inevitably return to cigarettes. She had become so discouraged that she reported she would often go several weeks without using the patch until she became motivated enough to re-attempt to quit and would put it on and try again. This was a long standing pattern on her part. She also reported that although she used the lowest dose possible (7 mg), she would frequently develop more sleep problems on the patch. When she was in high school she sought help in order to decide what to do with her future as she anticipated having problems with higher education. At this point she was evaluated and diagnosed. Medication was recommended, but she reports that she refused at that time because of a tendency to be nervous. She still did not want to consider it. When she was recruited for the study, she was unhappy at work as she found the hours long, the income unreliable and the relationship with her employer was tense. Her attempts to quit smoking did not improve her circumstances as she felt it often affected her mood. Her parents helped her financially although she lived on her own. Near the end of the treatment, she had a falling out with her boss and she decided to look for work elsewhere. Interestingly, although she smoked less than any other participant, she reported her addiction as very high on the outcome variables.

Participant B (CR). CR (50 years of age) worked part-time as a research coordinator in a medical office. She had no diagnosis of ADHD. She joined the study after completing the ASRS-18 and found to her surprise that she responded yes to a majority of the items (four on the initial six and 12 in total on the 18 item scale). Her initial FTND score was in the moderate dependence range (5). The IVA+Plus scores were 69 (moderate to severely impaired) for both the sustained auditory and visual attention scales. Her WSR self-report results (ADHD subscale) were six on

nine symptoms for inattention and zero on nine symptoms for hyperactivity/impulsivity. Other items endorsed were feelings of guilt, self-blame and indecisiveness (depression symptoms). Her WFIRS-S scale indicated she struggled with smoking primarily, followed by self-concept, and family relations (for which she reported she had consulted with a psychologist). The WFIRS-P confirmed some early difficulties with grades, being bullied by her brothers and sister, but she was a quiet child and did not attract attention. It was as a teenager that she struggled most with motivation and staying in school. Despite inconsistent grades, she was accepted to a university program out of province, only to drop out because she could not keep up with the workload. Some time afterwards, she became a single mother and returned to CEGEP to study nursing, determined to establish a career that would enable her to care for her son. She never married and felt that the financial and emotional burden of single-parenting explained her inability to stop smoking despite using a patch. She had also never been able to quit smoking definitively despite the fact that as a nurse, she knew she had to. She was on the lightest dose of the patch (7 mg) when she began the study.

Participant C (JW). The third participant (50 years of age) was recruited by Participant B who worked intermittently as a research coordinator in a medical practice. She also did not have a diagnosis of ADHD. Her FTND score was eight (very highly dependent). She marked four of six items on the ASRS-6 as significant and her IVA+Plus scores were 66 for auditory sustained attention and 64 for visual sustained attention (both in the severely impaired range). On the WSR (ADHD subscale) she reported six symptoms for inattention and one symptom for hyperactivity/impulsivity. On the WFIRS-S scale, smoking was signalled as a major issue, as well as items in the life skills subscale relating to keeping up with household chores, avoiding exercise, problems managing money, and problems getting to bed. The WURS confirmed long standing issues with school (not achieving up to potential), stubbornness, restlessness and distractibility,

disorganisation and impulsivity. JW was normally a very heavy smoker, more than 30 cigarettes per day, and at one point in her life she had smoked up to two packs per day. She had tried over ten times to quit smoking using various methods but was never successful. She worked as a bookkeeper, was married for over twenty years and had two adult children, both of whom had been diagnosed as children with ADHD. Her mother had abandoned the family when she was a child and she and her brother had been adopted by another family. Although she reports having been a handful as an adolescent, the circumstances were such that she was never referred for an evaluation. When she was recruited for the study, she was proud of what she had accomplished for herself and her family, but was unhappy that she could not quit smoking. She had been prescribed starting a cessation program with the highest dosage of nicotine patch (24mg).

Participant D (MT). This participant (44) had been diagnosed with ADHD by a well-known ADHD researcher and psychiatrist as an adult in her thirties. She was highly dependent when she joined the study (FTND = 7) although in early adulthood she had smoked more heavily. Her ASRS-6 and ASRS-18 scores were both very elevated (6/6 and 18/18). Her CPT scores were 77 for auditory sustained attention (mildly impaired range) and 90 for visual sustained attention (average range). On the WSR (ADHD subscale) she listed 7/9 inattentive symptoms, and 5/9 hyperactivity/impulsivity symptoms. She also endorsed several anxiety symptoms, but when queried, she said they would come and go depending on the severity of the family's financial stressors. The WFIRS-S indicated family problems, problems being late, life skills problems (managing money and getting ready to leave the house), and self-concept difficulties such as frustration and discouragement. She felt some of her stress and frustration could be alleviated if she could give up smoking. The WFIRS-P scale confirmed family impairment, school issues, life-skills deficits and risky behaviours as a child and adolescent. At the time of her diagnosis 10 years prior, she had an alcohol problem and was unwilling to take medication. She joined AA and

stopped drinking, but was never able to quit smoking entirely, (although she did manage to stop smoking during her pregnancy). She worked as a dog groomer and had been married five years to a partner with five children of his own. They lived in the country and she described her situation as chronically stressful given the familial and financial problems they experienced. Her mother was a significant source of stability, helping her in the care of her biological child, sharing custody so he could attend school in town. She was using the medium dose patch (14 mg).

Procedures

Participants were recruited by letters sent to medical offices and employee assistance programs in the West Island of Montreal. Given the bilingual characteristics of this area, all of the materials used in the study were prepared in both French and English, and the outcome measures were carefully chosen to be applicable to both languages. The letters presented the study and explained that the proposed treatment would supplement the use of a nicotine replacement therapy (NRT) for patients with ADHD who were struggling nonetheless to quit smoking. They were simply handed to interested individuals who then contacted the researcher. An initial telephone screening of nicotine dependence was performed using the Fagerström Test of Nicotine Dependence (FTND) (≥ 5), and attention problems were likewise screened using the ASRS v1.1 (at least four responses of sufficient severity to the first six questions). Additional inclusion factors were: being 18 years of age or older; being available for treatment; being able to freely provide informed consent to the study; and following an assessment, showing a sufficient number of ADHD symptoms as well as impairment in childhood (not due to other conditions) to potentially qualify for a diagnosis of ADHD. Seven individuals who met the screening criteria were invited to a first appointment at the investigator's office in Pointe Claire. All the potential participants were told they would be assessed for ADHD symptoms. None expressed interest in a formal diagnosis as their primary concern was to improve smoking cessation. A consent form that explained the treatment in detail,

including potential risks and benefits, was reviewed with them and they were given information concerning the treatment. Six participants accepted to proceed with the evaluation portion of the study and signed the consent form. Each participant was further evaluated for adult ADHD symptoms using the CADDRA Assessment Toolkit (The Canadian Attention Deficit Hyperactivity Disorder Resource Alliance - CAAT; the Wender Utah Rating Scale; the IVA+Plus (CPT). The CAAT was chosen because it is a comprehensive toolkit that includes a number of scales that cover the areas recommended for evaluation in adult clients with attention difficulties (Epstein & Weiss, 2012). One potential participant withdrew at this stage due to uncertainty about quitting smoking. During a second appointment, each participant underwent a quantitative electroencephalogram. Of the five participants who completed this stage of the process, only four accepted to proceed with the treatment phase of the study. (The participant who withdrew at this point cited time constraints as her reason for leaving.) Two of the participants presented with formal diagnoses of ADHD according to the DSM-IV-TR; one had been diagnosed with ADHD-combined type and the other ADHD, predominantly inattentive type. The other two participants were not interested in obtaining a more formal diagnosis as they were both well established in their careers, but they understood their inclusion was based on exhibiting sufficient symptoms to potentially qualify for a diagnosis. Exclusion criteria included: current pharmacological treatment for ADHD; a neurological or diagnosed psychiatric condition; drug addiction; an excess, according to the quantitative electroencephalogram (qEEG), of beta waves in the area where they were to be enhanced; and previous neurofeedback treatment.

The first participant was given the choice of choosing the first baseline length. Afterwards, additional participants were assigned to a baseline. Participants were provided with the scales for the daily measures (CDS-12 and CWS-21) and given an appointment for their first neurofeedback treatment. They were instructed to begin the monitoring using the scales on the prescribed day

preceding the start of the intervention phase. One participant (VB) began the monitoring for the baseline phase later than intended although she had been the participant given the choice of baseline since she was the first participant recruited. She also put off beginning the treatment phase for a variety of minor reasons (e.g., having to work late and missing the appointment, forgetting to show up, etc.). As such, her baseline phase was extended from 12 to 20 days. Another participant (MT) delayed the start of the treatment by one day so her baseline phase was extended from six days to seven. The other two participants, CR and JW began the treatment phase as established and their baselines were eight and ten days as planned. (IVA+Plus measures were scheduled following every 3rd treatment although several were missed by participants (see Appendix 9). Ten weeks following the last treatment, the FTND was reprised and an evaluation of smoking abstinence was done. (See Appendices 10 and 11 for the consent form and the recruitment letter.)

Ethical Considerations

Given that neurofeedback is not widely known as a therapeutic intervention, each participant was provided with a detailed description of the treatment and was shown the equipment to be used during the first meeting with the investigator (see Appendix 12). The main purpose of the qEEG was to prevent having participants for whom the proposed protocol might be iatrogenic, i.e. those who would already have an excess of SMR waves, when compared to a normative database, at C3 and/or C4. The results of the qEEGs were verified by an expert in qEEG analysis, Dr. Johanne Lévesque. The reports to date from neurofeedback practitioners suggest that undesirable side-effects are rare and when they occur, they disappear quickly (Sherlin et al., 2010). The main recommendation from leaders of the field is to ensure that a qEEG is done in order to minimize the risk of an ineffectual treatment (Hammond & Kirk, 2007). In addition, the design of the protocol necessarily took into consideration the need of participants to get on with the proposed treatment. Finding participants who met the inclusion criteria was not as rapid as anticipated and ultimately a

significant period of time elapsed between each successful recruitment. As such, a non-concurrent multiple baseline design was used so that participants did not have to wait unduly before beginning the neurofeedback.

Treatment

The betaSMR protocol used for this study is based on the attention protocol used in the Scott-Kaiser modification of the Peniston protocol, inhibiting 4-9 hz activity at C3/4-7 hz at C4, and enhancing 15-18 hz at C3/12-15 hz at C4. This protocol was developed and used extensively by the pioneer neurotherapists Susan and Siegfried Othmer who promoted bi-hemispheric applications of neurofeedback (Kaiser & Othmer, 2000). The participants for this study were asked to attend one hour training sessions three times per week at the office in Pointe Claire. Care was taken to schedule sessions during the same period of the day in order to ensure comparable training results during the study. The initial part of the hour was used to attach electrodes to the scalp at C3 and C4 using a mild skin preparation product (Nuprep) and Ten20 conductive paste. A reference electrode and a ground electrode on each earlobe were also secured. The electrodes were then plugged into a Procomp Infiniti amplifier from Thought Technology. The amplified signal from the brain was then transmitted to a computer which, using the Biograph Infiniti program (v.5.1.2) from Thought Technology, processed the signal and provided feedback to the user on the fluctuations occurring in their brainwaves. Feedback was both auditory and visual. In this case, participants chose from a selection of short audio visual interleave files and music. When they met the criteria established by the protocol and produced the desired brainwaves, the visual file advanced and music played. If the selected brainwave patterns were not present, the visual file stopped and the auditory feedback stopped as well.

The participants were provided twenty minutes of two-channel simultaneous bi-hemispheric biofeedback per session (4 x 5 minute training periods with breaks in between). They were

instructed to simply observe the feedback initially in order to engage without exerting undue effort. Eventually, they were told to see if they could learn to gradually change the feedback at will by associating changes in the signal with alterations in their breathing, attitudes, and thoughts. In this way a person can experiment with different ways to regulate the electrical activity of their brain. By concentrating to inhibit excessive slow waves and augment the desired fast waves, attention is trained to improve.

Results

This study is the first to consider the efficacy of neurofeedback as a treatment to manage withdrawal symptoms and reduce cigarette dependence through its effects on attention in individuals with ADHD. Single subject analysis is beneficial under such circumstances because it provides a closer examination of individual performance, essential for evaluating potential changes in each subject. Each participant serves as their own control, allowing for a close inspection of any change from the baseline to the treatment phase. The treatment phase ended when each participant had improved their IVA+Plus sustained attention scores to the average level (See Appendix 9). MT began the treatment with one of her IVA+Plus scores already in the average, but it was decided to try to achieve average scores in both modalities. One participant (JW) did not reach that goal but having completed 12 sessions of neurofeedback and having substantially improved her attention scores, her data was included in the analysis. Finally, VB only managed to meet the goal for her sustained auditory attention, although her sustained visual attention improved significantly as well.

The data points for the CDS-12 representing the two phases for each participant were plotted into a series of graphs which were then inspected to discern changes in level, trend or slope and variability as a result of the intervention. Because of a high level of variability in some of the data points, a new series of graphs was generated using the CDS-5. The Single Case Visual Analysis (SCVA) package developed by Bulté and Onghena (2012) was used to generate the graphs, which were then made equivalent in terms of scale to provide for visual comparability. The SCVA, is available at the developers' website, ppw.kuleuven.be/english/research/mesrg and was developed to aid in the visual analysis of single case data through the utilisation of central location and trend lines. Parker and Vannest (2012) recommend that visual inspection precede further analysis in order to enable the investigator to make valid decisions concerning the data to be analysed and the statistical method to choose to complete the analysis.

Visual Analysis

The changes in the mean from the baseline to the intervention phase in the graphs for the CDS-5 appear to suggest a positive treatment effect for three of the four participants (VB, RC, and JW), indicating decreased dependency as measured by the CDS-5 (see Figure 1). For MT, there was a slight increase in the mean from the baseline phase to the intervention phase. A horizontal

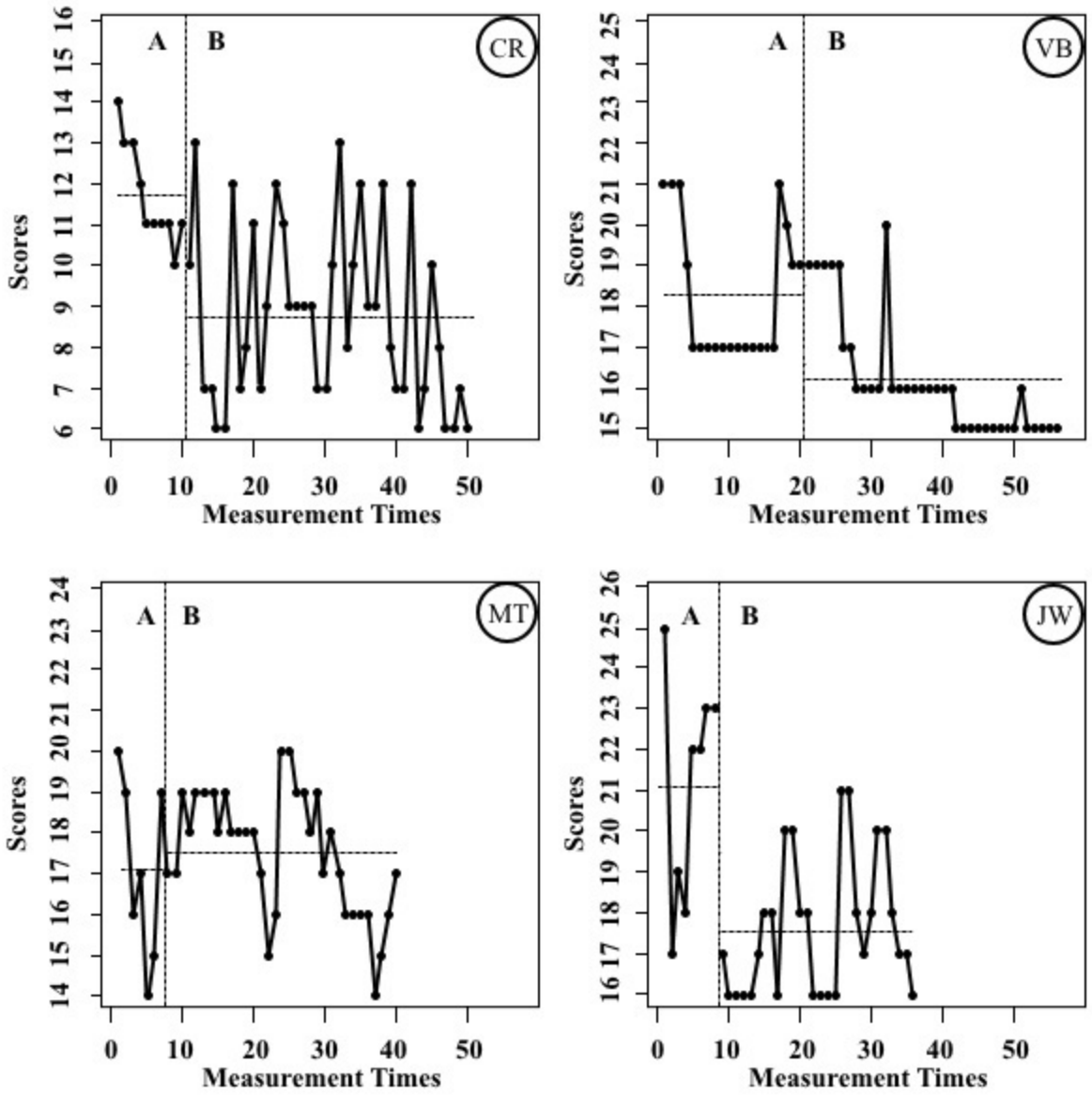

Figure 1. CDS-5 Mean

reference line is included by the SCVA package to assist in the visual inspection of the measure of central location. Upon visual inspection of the CDS-5 data points, it appears that the baseline data were not stable for all of the participants. Although it is preferable that baselines be stable for analysis of multiple baseline studies, it is not always possible in a clinical setting. Robust linear trend lines were generated to further assist the visual analysis in this case (see Figure 2).

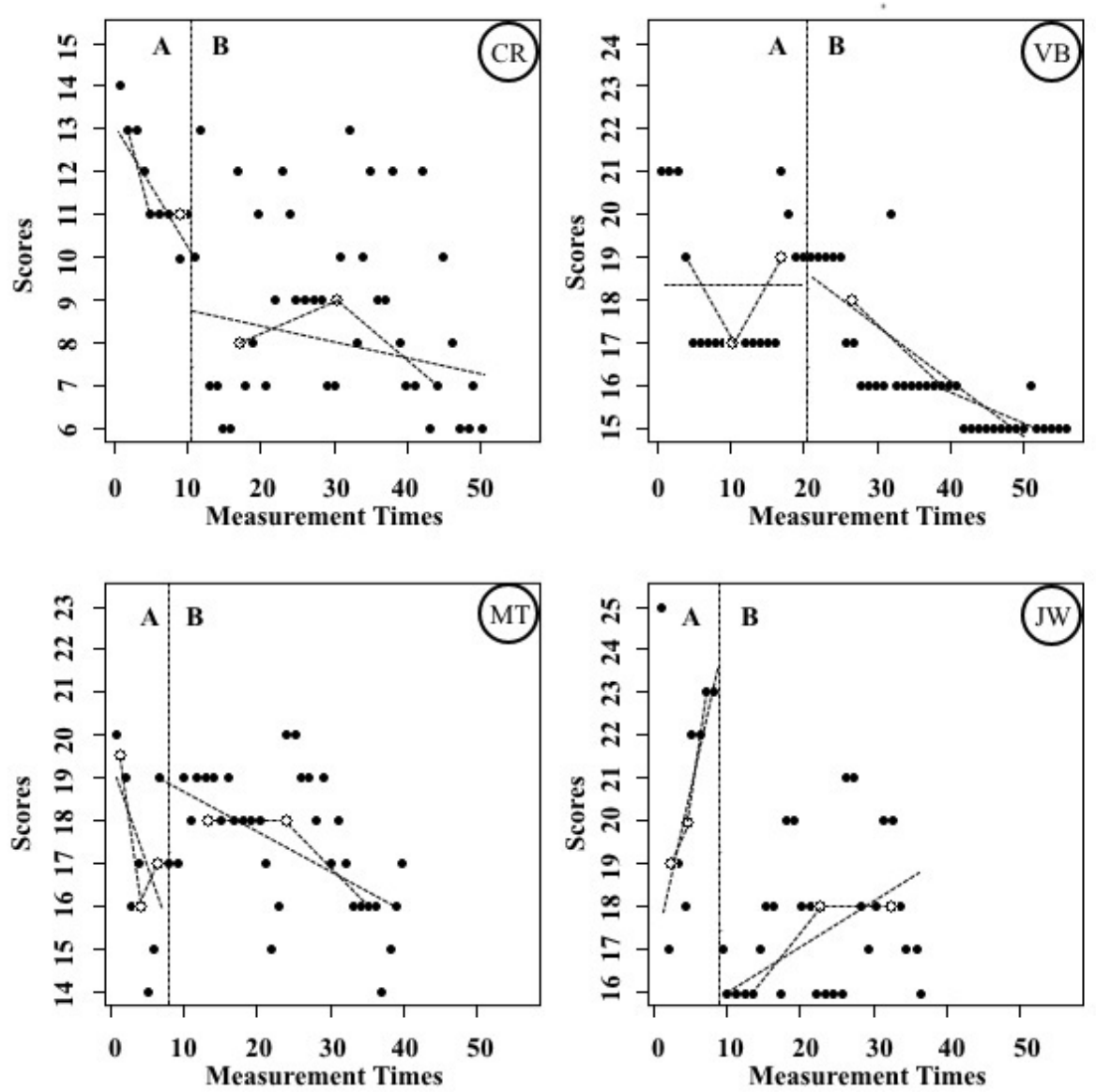

Figure 2. CDS-5 Trend

All but one of the participants (JW) had decreasing trends in the desired direction of the treatment effect in the early part of the baseline, followed by an increase (VB and MT) or a stabilisation (RC) of the trend in the latter half of the baseline. The heaviest smoker (JW) exhibited an increasing trend in the opposite direction of the treatment effect from the outset during the baseline phase. Baseline trends in the opposite direction of the desired treatment effect do not invalidate conclusions of a positive outcome should there be one.

The graphs depicting the intervention phases of the study also show a divergence between JW's results and those of the remaining three participants. Her trend line does not decrease during the intervention phase, although it stabilises in the second portion of the intervention. It is important to note however that she showed the greatest step diminution of dependence at the beginning of the treatment, as well as a shift in the slope of the trend line during the intervention phase as compared to the baseline. Although her trend line in the intervention phase is initially increasing, it eventually stabilises as a flat line. Given that neurofeedback is a gradual process, other factors are likely responsible for the step change, but the eventual flattening of the slope at a lower level than during the baseline can be considered a treatment effect.

The other three participants (VB, RC and MT) all show overall decreasing trends in the intervention phase. Participant VB had a decreasing trendline beginning several days into the treatment. This is consistent with the purported effects of neurofeedback which, unlike medication, produces subtle and gradual changes in neuronal networks over time. Two participants (RC and MT) did not show a diminishing trend at the outset of the treatment, but both exhibit decreasing trendlines in the later days of the intervention phase. They also had the greatest variability in terms of their measures of dependence. The overall step change for RC is apparent, but it is not so for MT, visible in the slight increase in her mean scores from the baseline to the intervention phase.

Visual inspection of the CWS-21 data which measures withdrawal symptoms as an aggregate, showed the following results. Differences in level between the phases appear to be minor for all participants but MT (who had a larger decrease in overall withdrawal symptoms), although VB also exhibited a decrease (see Figure 3). (Recall that MT was the only participant who showed a minor increase in her dependency scores as measured by the CDS-5).

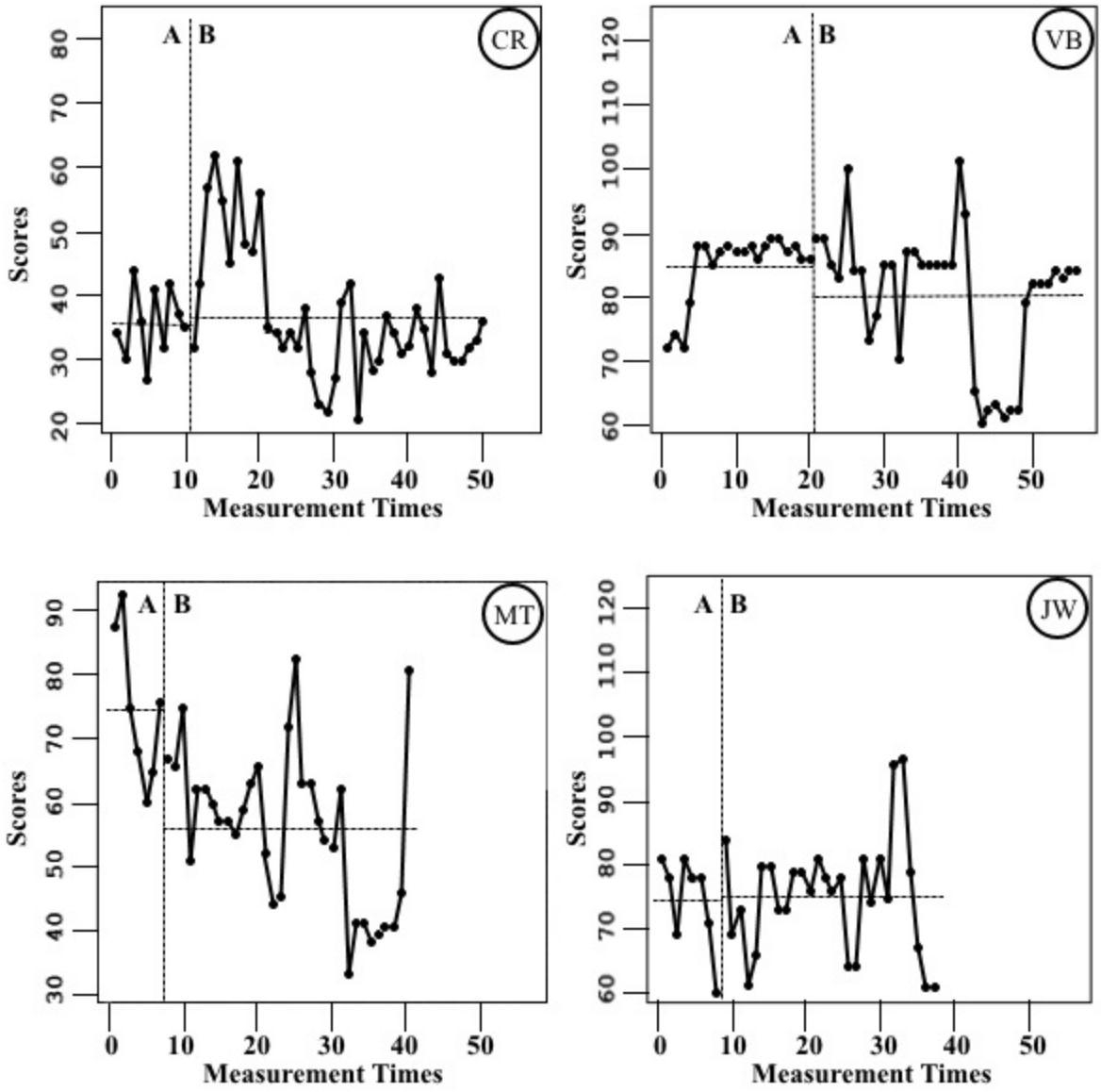

Figure 3. CWS-21 Mean

As for trend (see Figure 4), both JW and MT reported overall decreases in withdrawal symptoms during the baseline phases. These trends were reversed (for MT the reversal began in the latter part of the baseline) and became an increasing trend which continued during the initial part of the treatment phase, only to once again reverse to indicate a decrease in withdrawal symptoms in the latter part of the treatment phase. (Both JW and MT were much heavier smokers than VB and RC.)

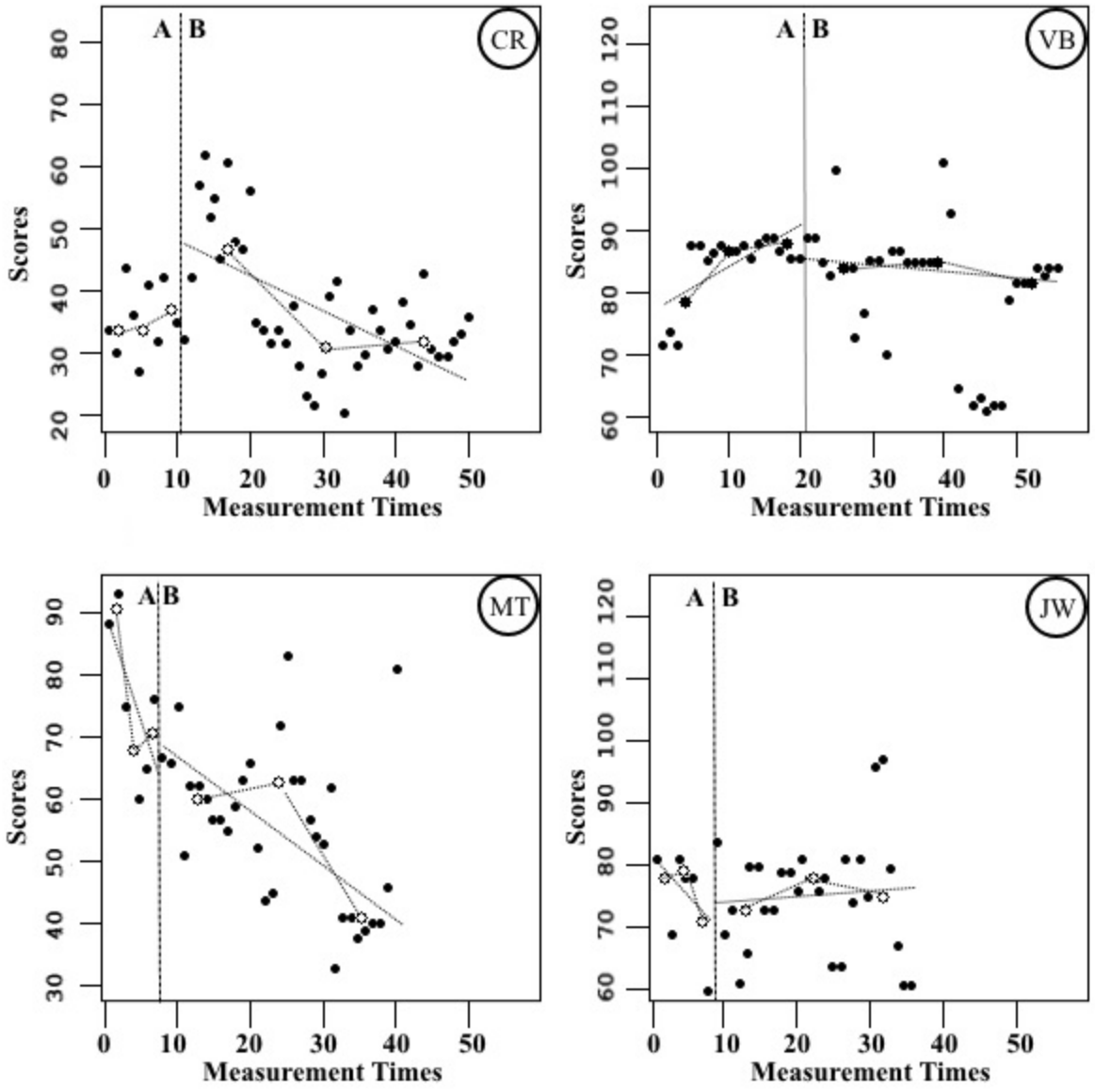

Figure 4. CWS-21Trend

Participant RC had a temporary increase in withdrawal symptoms when the neurofeedback treatment was initiated. There was however no appreciable difference from the baseline phase to the latter part of the treatment phase in RC's CWS-21 data. VB's trend line graph was more difficult to interpret visually. She reported increases in withdrawal symptoms during the baseline, but the variability of the data points in the neurofeedback phase made it unclear as to whether there was an overall decrease.

It is helpful in situations where the visual analysis is ambiguous to have access to statistical methods to interpret the data. The Tau-U analysis that follows quantifies the tendencies described above. It is especially useful in cases, as this one, when the data is highly variable, and the baseline is not stable and so was the ideal choice for further analysis of the results/

Tau-U Analysis

The Tau-U is a non-parametric method that can be used to measure the effectiveness of treatment by considering the percentage of data points during the intervention phase that do not overlap (PND) with the baseline data points, an idea similar to that of an ROC analysis (Parker, Vannest, Davis, & Sauber, 2011). Normally, PND analysis, which is insensitive to trend, is not useful when there is an undesirable trend in the baseline phase. For two participants (RC and VB), there appears to be somewhat of a trend (albeit one that reversed or stabilised) matching the direction of the desired treatment effect for the CDS-5.The other two participants (JW and MT) also exhibit trends in the baseline but in the opposite direction of the desired treatment effect, which is less of a challenge to the interpretation of a positive treatment effects. For the CWS-21, undesirable baseline trends appear in the data for JW and MT. In order to address these issues, this study used the Tau-U method to analyse the data. Named after its parents Kendall's Tau and Mann-Whitney U, Tau-U can control for a baseline trend, resulting in an index which interprets

the percent of data that improve over time in any profile, not only in a straight line (Parker & Vannest, 2009). The method also provides a p-value and Z scores (see Table 1).

Table 1 Results of the CDS-5 and CWS-21 Tau-U Analyses for Baseline Trend

Participants	Baseline Tau-U CDS-5	Baseline Tau-U CWS-21
VB	-.0789	.3263
RC	**-.7111**	.11
JW	.3571	**-.50**
MT	-.381	**-.4286**

(Tau-U > 40% indicates a significant trend)

The first step of the statistical analysis was to assess whether the undesirable baseline trends were significant. To establish which baselines required an adjustment, a web-based Tau-U calculator was used (Vannest, Parker, & Gonen, 2011). Parker has recommended that Phase A datasets with ≥ .40 should be selected for baseline control (Parker et al., 2011). Only one of the baselines (*RC = 71%*) exceeded *.40* for the CDS-5 data. For the CWS, two deteriorating baselines were identified, JW and MT (Table 1). For JW, the Tau-U was *50%,* and for MT it was *42%.*

The calculator was then used to compare each baseline phase to its corresponding intervention phase to provide an individual effect size for the CDS-5 (after correction of the baseline for Participant RC). The results are summarized in Table 2 which includes Z scores and p-values. Three participants registered decreases in dependency as measured by the CD-5 (VB = *-74%,* RC= *-63%;* JW = *-72%*). The only participant not experiencing at least a moderate treatment effect as measured by the CDS-5 was MT (*-8%*).

Table 2 Comparison Results of the Tau-U Analyses for CDS-5 (Phase A vs Phase B)

Participants	A (baseline) versus B Tau-U	p-value	Z-score
VB	**-.7361**	.000	-4.5314
RC	**-.6325*** *(.71)*	.0022* *(.0005)*	-3.0681* *(-3.46)*
JW	**-.7232**	.0021	-3.0821
MT	-.0779	.7487	0.32040

(Tau-U > 40% indicates a significant trend)
*indicates a comparison with a corrected baseline
(Italics indicate the Tau-U analysis with the alternate baseline results for those participants with baseline trends that are significant.)

Individual effect sizes were then grouped to provide an overall effect size for the study. A weighted average of all four participants was found to be Tau-U *-.5346* with an overall Z score of *-5.9614*, a confidence interval of *-.3587 to -.7106* at *90%* and a p-value of *0*.

The Tau-U analysis of the aggregate CWS-21 scores was conducted in the same fashion. The baselines for JW and MT were corrected (see Table 1), then phase A was compared to phase B for each of the participants (see Table 3).

Table 3 Comparison Results of the Tau-U Analyses for CWS-21 (Phase A vs Phase B)

Participants	A (baseline) versus B Tau-U	p-value	Z-score
VB	**-.444**	.0071	-2.6932
CR	-.0525	.799	-0.2547
JW	.0759**(.0134)*	.7464* *(.9545)*	0.3234**(.0571)*
MT	**-.71*** *(-.7489)*	.0035* *(.0021)*	-2.9188* *(-3.079)*

(Tau-U > 40% indicates a significant trend)
*indicates a comparison with a corrected baseline
(Italics indicate the Tau-U analysis with the alternate baseline results for those participants with baseline trends that are significant.)

A very modest diminution of withdrawal symptoms was recorded for VB (*-44%),* and a more significant improvement in symptoms occurred for MT (*-71%).* The CWS-21 weighted average was found to be Tau-U *-.2797* with an overall Z score of *-2.611*, p-value = *.0090*, and a confidence interval of *-.1035* to *-.4559* at *90%.*

The CWS-21 was composed of six subscales of symptoms: depression-anxiety; craving; irritability-impatience; difficulty concentrating; appetite-weight; insomnia. Each baseline was verified for trend followed by a comparison of Phase A to Phase B (see Table 4). In terms of the baseline trends, VB showed a modest increase in depressive symptoms during the baseline (*45*%). JW and MT had the same increase in depressive symptoms during the baseline (*52*%). MT also had significant decreases in craving and irritability during the baseline phase, whereas JW had an overall decrease in sleeping problems (*48*%).

After the baseline correction, the comparison of the baseline phase to the neurofeedback intervention phase for the CWS-21 subscales revealed no consistent patterns but for one participant. Despite no real change in her CDS-5 scores, the CWS subscales for MT showed significant decreases in certain withdrawal symptoms (craving = *-72%*; concentration = *-85%;* appetite = *-79*%). Only craving appeared to respond to the treatment for more than one participant (VB and MT). Both of these participants had higher levels of ADHD symptoms. The only other change was a decrease in the depression-anxiety scale for VB. The participants with a lesser number of reported ADHD symptoms (CR and JW) had no real change in terms of their withdrawal symptoms, although JW (the heaviest smoker) did show a tendency to report slightly more symptoms. No participant however exhibited any increase of significance in their withdrawal symptoms as measured by this scale.

Table 4 Results of the Tau-U Analyses for CWS-21 Subscales (Baseline and Comparison)

Subscale	A (baseline)	A versus B		
	Tau-U	Tau-U	p-value	Z-score
Depression-anxiety				
VB	**.4474**	**-.4543***	.0054*	-2.7819*
CR	.1778	.32	.1206	1.5522
JW	**-.5238**	.2092*	.3979*	0.8454*
MT	**-.5238**	-.2424*	.3189*	- .9967*
Craving				
VB	.2053	**-.5443**	.0009	-3.331
CR	.0667	-.185	.3695	-0.8974
JW	.0476	.2806	.2568	1.1341
MT	**-.8947**	**-.7229***	.003*	-2.9722*
Irritability-impatience				
VB	.0737	-.02	.9025	-0.1225
CR	-.2444	-.13	.5283	-0.6306
JW	-.1905	.0714	.7728	0 .2887
MT	**-.5714**	-.3506*	.1494*	-1.441*
Difficulty concentrating				
VB	-.1105	.03	.8542	0.1837
CR	-.0222	0	1	0
JW	-.1429	.1378	.5567	0.5777
MT	-.1481	**-.8462**	.0007	-3.3908
Appetite-weight gain				
VB	.2579	.05	.7621	0.3028
CR	-.1556	-.3532	.0991	-1.6492
JW	0	.1786	.4705	-0.7217
MT	-.0952	**-.7922**	.0011	-3.257
Insomnia				
VB	.0684	-.16	.3272	-0.9798
CR	.2444	-.12	.5605	-0.5821
JW	**-.4762**	.148*	.5499*	0.598*
MT	.1429	.1039	.6693	0.4271

*indicates a comparison with a corrected baseline
Bolded figures indicate significant trends

To evaluate abstinence, the FDA recommends a four week period of complete abstinence to establish the efficacy of a smoking cessation treatment (Hughes et al., 2003). Only one participant, CR, achieved such a level of abstinence at the time of the follow-up. Two others continued to smoke albeit fewer cigarettes per day than prior to the study (VB and RM) and with a reduced dependency as measured by the FTND. One participant did not respond to the subsequent follow-up (JW). The ten week follow-up with the FTND (which was originally required to be $\geq$ 5 indicating moderate or more heavy dependence) was as follows: VB= 2; CR= 0; MT= 3 indicated a change to very low, zero and low dependence. (For original FTND scores, see Appendix 8). The significant change in the final FTND scores corroborates the trend of the changes in the CDS-5 reports.

Discussion

Neurofeedback is learning – learning that is based on operant conditioning principles using a biofeedback to become aware of brainwaves that normally are not accessible, and therefore not usually amenable, to being shaped purposefully (Arns, Heinrich & Strehl, 2013). Like most shaping, this is a gradual process, requiring many repetitions before producing more enduring change. "Each time the designated event occurs, the instrumentation provides a signal indicating this to the trainee. If the signal is perceived as desirable, then the brain will spontaneously learn to achieve the state that leads to the signal, over a long number of trials." (Collura, 2014, p. 16). Although some sensitive individuals can very quickly become aware of what is happening, evidence of a shift is usually apparent only after a delay. As in all learning processes, the time required is a very individual matter and can vary to some extent, but clinical reports reveal that betaSMR protocols on average show some results in as little as eight sessions (Vernon et al., 2003) although it can take many more to anchor the new learning. Scott et al. (2005) reported an average of 13 sessions in the original Scott-Kaiser study before normalisation of attention scores in their study, composed of individuals in a treatment program for mixed substance abuse. Similarly, one would expect that it is not when the treatment was introduced in this study that benefits would appear.

Three of the participants (CR, VB & MT) had decreasing dependency score trends at the outset of the study during the initial portion of the pre-intervention phase (Phase A), whereas one participant (JW) appeared to increase her dependency during the baseline phase. Normally, a decreasing baseline would present a challenge to any conclusion that there was a treatment effect. It was possible with the use of the Tau-U analysis, to account for the decreasing trends across the baseline when taken as a whole and nonetheless conclude with confidence that there were moderate effects at play in this study that supported the hypothesis. A closer analysis of the trends

*within each phase of each case study s*uggests even stronger support that neurofeedback diminished dependence on nicotine for the participants trying to quit smoking.

Examining the initial and latter sections of each single case (see the regression trend lines in Figure 2) reveals that the three decreasing trends were either reversed or flattened just prior to the introduction of the treatment during Phase B. Whatever factors produced the initial decrease in the dependence scores appeared to no longer exert influence on the scores as time went on. Then, following the start of the neurofeedback training (Phase B), two of the participants (CR & JW) exhibited increasing trends in terms of their dependency scores for the first half of the intervention. The other two (VB & MT) had either a decreasing trend, (which in the case of VB was a reversal of the end of the baseline trend), or a flat trend (MT). Again, an examination of the regression trend lines in the latter half of the intervention phase would suggest that *all* the participants were ultimately responding to the intervention. Three participants (CR, VB & MT) showed decreasing trends in terms of their dependency scores as measured by the CDS-5 and one subject (JW) showed a flat trend at a lower level of dependency than during the baseline phase. As stated, neurofeedback should exert a gradual influence on behaviour. The fact that all of the participants showed decreasing or lower dependency trends in the *latter* half of the intervention phase would suggest that these results were potentially due to the betaSMR training they obtained.

As in previous research looking at nicotine dependency in this particular population, the combined results, including the withdrawal subscales, point to the complex interplay of psychological and physiological factors that can affect smoking behaviour and perceptions of dependency on the part of the participants. An examination of each single case individually will exhibit in greater detail how some of these additional elements (such as severity of dependence, hyperactivity/impulsivity symptoms, psychological and psychosocial factors, and the choice of a

quit date) may have had an impact on the results. Potential explanations looking at the mechanisms underlying these elements will ensue.

Self-Efficacy, Severity of ADHD and Nicotine Dependence within the Single Cases

Participant A (VB) was the first participant to join the study. Initially, fixed baseline lengths had been worked into the design of the study in order to randomise participants to a particular baseline and thereby benefit from more traditional statistical methods of analysis. VB as the first participant was given the choice of the first baseline length, and all other participants were to be randomly allotted to their baselines as they subsequently joined the study. This plan was revised when VB instituted several delays to the start of Phase A. She ultimately began only after two other participants had already started. This was the first clue that although she had stated she was determined to continue her efforts to quit smoking when recruited, VB's resolve perhaps wavered. She might have viewed the start of Phase A as a potential new quit date and at the last instance was hesitant to commit. The willingness to quit is regarded as insufficient as people often fail to act on their intentions (de Vries, Eggers & Bolman, 2013). A quit date signals a shift from an intention or willingness to quit to the enactment of a plan to quit. It can therefore have a significant impact on behaviour change in smoking cessation. Once VB had set a quit date (the decision to begin completing the scales), she began to reduce her smoking even though nothing had as yet changed. This is one possible explanation for the descending trend lines in the CDS-5 during the baseline phases of the study, not only for VB, but for two other participants as well (CR and MT). (Although the study design called for a target date to begin each phase, these dates were never intended as potential quit dates given that all of the participants were already involved in a smoking cessation treatment with a nicotine patch, albeit a non-successful one.)

Even after having started Phase A, VB then delayed the beginning of the treatment resulting in a longer baseline phase then initially intended. She was very unsure of her capacity to quit even with

the added treatment. This could be interpreted as a sign of a lack of self-efficacy. A lack of confidence in her ability to reduce her dependence is suggested by her consistently high ratings on the first question of the CDS-12, "rate your level of addiction to cigarettes" during both phases of the study. She gave herself the highest possible score (5 = extremely addicted) regardless of any other changes that occurred. For example, VB eventually smoked fewer cigarettes per day than anyone else and began reporting a significant delay the first cigarette of the day (strong indicators of weakening physiological dependency). High self-efficacy and self-confidence in one's ability to quit predict actual quitting (Etter, Bergman, Humair, & Pernegger, 2000).

Another possible explanation for the descending baseline trend is the impact of the self-monitoring inherent in the completion of the scales. A daily measure of their smoking behaviour and the impact on their well-being and health may have produced a renewal of their efforts to quit and possibly even a more consistent use of the patch during this period. (Not all of the participants appeared to have viewed the start of Phase A as a "new" quit date. JW actually increased the number of daily cigarettes smoked right up to the start of the intervention phase resulting in a steady increase in dependency scores, followed by a significant step change the day the intervention began.)

VB was one of the two participants who entered the study with an established diagnosis of ADHD and she reported more hyperactive/impulsive symptoms as well (see Appendix 8). Her initial IVA+Plus scores were unusually low but may have been influenced by excessive caution on her part when responding to the prompts during the first trial of the CPT (she said she was worried about not doing well). The opening evaluation in the study revealed she was plagued from time to time with insomnia, anxiety and mood swings, and had struggled with possible learning difficulties, which is par for the course for some individuals with ADHD. At the start of the baseline phase, her depression/anxiety scores on the withdrawal scale increased, then, as the

treatment was initiated, the trend reversed and they decreased significantly albeit moderately - despite leaving her job just near the end of the treatment due to increased conflict with her boss. Depressive symptoms have also been linked both with ADHD status and with smoking relapse, both prior to and following a cessation attempt (Etter, 2005). The question which must remain unanswered is whether or not VB struggled with these issues in the period just prior to joining the study and what impact (or not) her participation in the treatment had on her self-efficacy and depressive mood, and eventually on her capacity to become abstinent.

Participant B (CR), by contrast, was very motivated to begin as quickly as possible. In her case, the baseline was shortened in order to respect her schedule. While doing the neuropsychological tests that accompanied the initial assessment, CR exhibited confidence during several of them. Interestingly, although her attention scores as measured by the IVA+ Plus improved throughout, she did not report any change in her concentration level (as measured by a self-report subscale of the CWS-21) from the baseline phase to the treatment phase (in contrast to her assessment and to her CPT scores). Perhaps this discrepancy is explained by the fact that this participant was the only one to report using mnemonic strategies when evaluated with the Brown Peterson Trigram. Such techniques reveal her efforts to overcome her childhood and adolescent difficulties in attention. In addition, she revealed that she had pursued psychotherapy on several occasions to help her work on her emotional and family problems. So although CR was the participant with the greatest number of reported co-morbid symptoms at the outset of the study, she had achieved professional stability and was confident in her skills and competency as a nurse. She was also the participant who had the least reported ADHD hyperactivity/impulsivity symptoms and the lowest levels of nicotine dependency. Severity of dependence and level of ADHD symptoms have been shown to have an impact on smoking cessation. It was found that participants with ADHD-Inattentive subtype were more likely to achieve abstinence with a placebo than with medication as an adjunct

treatment to the nicotine patch (Covey et al., 2011). CR was the only participant to report having successfully quit smoking at the 10-week follow-up after terminating treatment.

MT not only reported a higher level of dependence initially (FTND = 7), she also indicated the most ADHD symptoms on the ASRS-18 (18 of 18) and a number of current stressors on the functional assessment. Consistent with the findings of persistence of ADHD symptoms into adulthood, there was significant impairment throughout her life span. Severity of ADHD symptoms has been shown in similar studies such as this one to alter the efficacy of the treatment. When smokers were treated with OROS methylphenidate and a nicotine patch, only those with more severe symptoms of ADHD eventually benefitted from the treatment (Nunes et al., 2013). Smokers with less symptoms of ADHD were actually hindered by the medication in their attempts to quit in this analysis. MT finished the study with a significant improvement in both her CDS-5 scores and the final FTND score, which corresponds with the findings reported above concerning heavier ADHD symptoms. In this study however, even participants with less ADHD symptoms found the treatment beneficial.

When recruited, MT had been using the patch inconsistently (due to financial strain). In order to participate in the study, she committed to stabilizing her patch usage while enrolled, but it is possible her use of the patch prior to the start of the study had an impact on her cigarette use and withdrawal symptoms during the study, even though the treatment was not totally new to her. The decreasing trend in terms of withdrawal symptoms eventually stabilized and even increased briefly as the study progressed, eventually decreasing again with no change in patch usage. It should be mentioned that this participant was experiencing the greatest level of psychosocial stress during the study. She had been waiting several months for an operation for carpal tunnel syndrome. She was called halfway through the intervention phase, and although she did not miss any training because the operation was an outpatient intervention, she had to book off work. This caused the

family significant financial pressure. Then, upon her return to work, MT was told her position was to be abolished at the end of the season. It is very possible that these additional stressors stymied her eventual abstinence although as can be seen in a visual inspection of the trends, she ultimately did appear to benefit from the treatment (in addition to her own verbal report) before meeting the stop condition for the study (normalisation of IVA+Plus score).

The other heavy smoker of the participants, JW, did not meet the condition for stopping the treatment and although she dropped out of the study before meeting the stop criteria, there was sufficient data to include her in the analysis. In her case, the decreasing withdrawal symptoms during the baseline phase appear to be related to an increase in smoking prior to Phase B (see CDS-5 results in Table 3 for this participant). As previously mentioned, once the treatment began, there was a significant step change in her dependency scores which were not likely due to the neurofeedback treatment given the gradual effect of the training, although the stabilisation of her scores in the latter half of the intervention phase could most likely be attributed to the effects of the betaSMR protocol. JW's sustained attention scores never normalised, but they improved dramatically from 66 to 73 (standard scores) for sustained auditory attention, and from 64 to 83 for sustained visual attention. It is perhaps noteworthy that although JW did not report current hyperactive/impulsive symptoms during the intake process, she did report having such difficulties as a teenager. The higher levels of symptoms earlier on in life may have ultimately contributed to a higher level of dependency on nicotine for this participant. It should also be mentioned that JW suffered from bouts of arthritis pain and had several episodes during the study. This may also have been a factor in her significant dependency on nicotine.

Craving and Hyperactivity/Impulsivity versus Attention

In terms of the withdrawal symptoms that were examined, there were no replications of significant changes across all the participants for the six subcategories included. The only potential

pattern of note was the significant reduction in craving for the two participants (VB = *-54%;* MT = *-72*%) who entered the study with higher levels of ADHD hyperactivity/impulsivity symptoms. Craving is a particularly important aspect of the withdrawal syndrome as cigarette craving can significantly contribute to relapse during cessation attempt, particularly for clients with ADHD (Canterbury et al., 2013; Etter, 2005). Although some investigations have suggested medication for ADHD can reduce craving in a smoking cessation context, further analysis has revealed that there is an overlap between ADHD symptoms and withdrawal symptoms. Once ADHD symptoms are controlled for, only craving as a withdrawal symptom is not reduced by medication (Berlin et al., 2011). For individuals with more pernicious ADHD for whom cigarette cessation can be more of a challenge that other people, a treatment that addresses their craving while decreasing ADHD symptoms could be especially helpful. MT, who was the participant with the greatest impact of ADHD symptoms on her functioning by far, seemed to benefit the greatest from the treatment in terms of the impact on withdrawal symptoms (see Table 4). Finally, there is some evidence showing that women with ADHD in particular experience an increase in craving with abstinence (McClernon et al., 2011).

A possible explanation for the effect on craving of the treatment used in this study, especially for those with higher scores on the ASRS-18 scale, comes from recent work with real-time fMRI (rtfMRI) neurofeedback and smoking. These investigations use the blood oxygenation level-dependent (BOLD) response to modulate neural activity fed back to them by the rftMRI (Hartwell et al., 2013). It was found that when non-ADHD smokers were exposed to videos designed to elicit craving, they exhibited an increase in brain areas associated with attention and motor planning (Smolka et al, 2006), as well as a decrease in deactivation of part of the default-mode network (Claus et al., 2013). The authors concluded that these smokers had an attentional bias toward smoking cues and were potentially more engaged in a self-referential process that monitored

somatic sensations intensifying craving, triggering an automated response to cigarettes by an increased engagement of sensorimotor and motor preparation circuits. Others have speculated that this relationship is amplified in individuals with ADHD, explaining that as the severity of symptoms increases, craving is intensified (McClernon, 2009). Although the betaSMR protocol has often been shown as more effective in improving attention, with lesser effects on hyperactivity, theoretically it acts upon the sensorimotor cortex therefore it should have an impact on adult hyperactivity/impulsivity symptoms that are ultimately modified as attentional biases are modulated. This research is especially relevant given that the betaSMR neurofeedback protocol utilised in this study has been shown to act upon the default mode network in participants with ADHD (Russell-Chapin et al., 2013).

Role of the NRT

The literature on neurofeedback and substance use disorders unequivocally states that neurofeedback is not a stand-alone treatment for addiction (Sokhadze, Cannon & Trudeau, 2008). Of course, most of this work has been done on populations with primary addictions other than cigarettes, and therefore involves co-morbidities such as depression and conduct disorder or personality disorders that are not necessarily implicated in cigarette smoking. The brain and EEG alterations that result from the use of substances such as cocaine and alcohol further complicate neurofeedback applications with these disorders. But it is known that smokers also have alterations in the brain such as reduced gray matter volume in pre-frontal cortical areas and different distributions of nicotinic receptors (McClernon, 2009). Pre-existing ADHD symptoms that are often associated with stimulant preference in choice of drug might further predict that neurofeedback alone would be ineffective in dealing with the dependence and withdrawal syndrome as well as the underlying condition. These considerations led to the choice to offer neurofeedback as an additional intervention to people already using nicotine replacement treatment

unsuccessfully rather than offer neurofeedback alone. That being said, the additional variable of nicotine delivered by a patch would have inevitably had an impact on the dependence and withdrawal symptoms being observed.

Studies that have tracked withdrawal symptoms in general populations who successfully quit smoking reveal a peak within a few days of abstinence, followed by an eventual decrease of withdrawal symptoms (Dawkins, Powell, Pickering, Powell, & West, 2009). A disruption in concentration and other factors within the CWS-21 was therefore to be expected as dependency scores decreased. There is a great deal of research confirming the disruption of attention in ADHD (and non-ADHD) smokers when they refrain from smoking (McClernon & Kollins, 2008). This was not observed consistently in the self-reported data across the participants. The presence of the NRT most likely played a role in cushioning participants from a worsening of some withdrawal symptoms, even as dependency scores diminished, but one would have expected greater difficulties for the heavier smokers, as well as for those with more severe ADHD symptoms. In addition, although the measure of sustained attention eventually increased for all of the participants in this study, (even partially normalising for three of the participants), there was no consistent pattern that was discernible as treatment progressed (see Appendix 9), particularly for the heaviest smokers (JW & MT). It appears that attention as measured by the sustained attention index of the IVA+Plus was affected by something other than the intervention. (A practice effect would have produced consistently increasing scores as well.) There is even some indication that an excess of nicotine can interfere with this form of attention. Did the NRT become excessive as the nicotine intake through smoking decreased and as the neurofeedback treatment became effective? One study reported that individuals with ADHD with higher levels of attentiveness showed a nicotine-induced decrement on measures of sustained attention (Poltavski & Petros, 2006).

Of course, the aim of the study was not to correlate discrete changes in attention with the moment to moment changes in nicotine dependence. Such an objective would have required very sophisticated measures of both nicotine and attention as well as very tight controls of the intake of nicotine, something that was not included in the design of this small study which left the usage of the patch in the hands of the participants and their medical practitioners (although no changes were reported for the duration of the treatment). The measure of attention was used primarily to identify a termination point for the treatment. The NRT was necessary as an adjunct treatment for ethical reasons, but it remains as a confounding element in the interpretation of the observed results.

Ultimately, the purpose of this project was to explore the usefulness of neurofeedback in a smoking cessation context for clinical work. To that end, this study suggests that neurofeedback could potentially reduce tobacco usage in a vulnerable population. Futhermore, the non-exacerbation of potential side-effects is a significant benefit. The main drawback is the time commitment that is required to achieve lasting results. This difficulty can be attenuated in several ways. Although the design and supervision of the training should be carried out by a licensed practitioner, the actual training is a relatively straightforward procedure and can be taught to family members or the trainee themselves in order that they continue supervised training at home. Neurofeedback can also be combined with any number of treatments such as medication, hypnosis, psychoeducation and psychotherapy (Soutar & Longo, 2011).

Limitations

Although single case research is gaining ground in terms of its usefulness in clinical settings, especially as analysis methods are refined, results must nonetheless be interpreted with caution and generalizing to other settings should be avoided. In addition, the assumption that the people recruited were sufficiently alike in order to compare treatment effects across participants was especially not clear in this case given the heterogeneity of the clinical presentations of ADHD, a

difficulty inherent to ADHD research. Participants had varying levels of inattention and impulsivity. The measures of smoking dependence also produced unexpected variability within both phases, although variability was decreased with the use of the CDS-5. It would have been preferable that the baselines of Phase A be more stable before the introduction of the treatment although the utilisation of the Tau-U permitted that factor to be diminished. The Tau-U is, however, a relatively new method of analysing single case research and it remains to be seen if the method for controlling baseline trend will be accepted and if the effect sizes it produces will be in line with the effect sizes of other more established statistical methods.

There are several EEG profiles that are associated with the strengths and deficits of ADHD. It appears therefore unlikely that a single standard neurofeedback protocol, even SMR training, would be the ideal approach to addressing underlying brain anomalies in order to improve target behaviours. Although for research purposes, standardised protocols are used to provide more control of variables within a study, studies that have matched the brain profile to the neurofeedback protocol appear to have had greater success with larger effect sizes reported (Monastra et al., 2002; Arns et al., 2012b). This study did assess participants with a 19-channel qEEG, but only to ensure that there were no focal anomalies or contraindications to the protocol being used. In addition, participants were not reassessed at the end of the study. The importance of the qEEG is growing steadily, not only in the field of neurofeedback but in neuropsychology and neurology as well. Future work should consider using the qEEG to guide protocol choice, as well as to provide pre-and post measures.

Participants were asked to follow medical advice as to the use of the NRT for the duration of the study. Subsequent inquiries that include an NRT should consider tracking possible changes in the use of the product just prior to the start of the study, as well as after the end of the treatment phase. In this case, participants did not signal any change during the active portion of the study,

but there were perhaps changes just before or after that may have affected outcomes. Furthermore, it would be useful to investigate the impact of neurofeedback on nicotine dependence and attention in smokers with ADHD who are not actively trying to quit and therefore not receiving smoking cessation treatment at all, thereby avoiding the confounding factor of the NRT.

Self-reports were the basis of the outcome measures. The validity of self-report outcome measures in smoking studies has frequently been questioned and although they have for the most part been found to be fairly accurate, the recommendation ultimately is to include a physiological measure to corroborate self-reports of changes in smoking behaviour (Patrick et al., 1994). Although the cost of such a tool was beyond the scope of this study, it would be an additional means to verify outcomes in future research. Such a tool would have allowed a verification of compliance of the use of the NRT.

It was not always possible to have the volunteer participants stay for the extra half hour to complete the IVA+Plus following their last weekly training session. On several occasions, the CPT measure was not obtained. On one occasion, the data was lost when the trainee inadvertently exited the program. Despite the fact that attention was not one of the dependent variables in this small study, it would have been useful to find better measures of attention or perhaps a measure of a broader deficit such as executive functioning to deepen the understanding of the impact of the neurofeedback training. Executive functioning issues were evident in the difficulties that occurred as pertains to scheduling and symptom reporting by the participants. Three sessions per week were requested of those who were recruited in the belief that they would benefit more from more frequent training, but on occasion participants showed up only once or twice per week. Given the significant demands of the assessment, training and monitoring of participants, twice weekly sessions would have perhaps produced more consistent data collection. Although

anecdotal evidence indicates that twice weekly training is sufficient for relieving problems of attention, most addiction studies are done in an intensive fashion, often daily. This aspect of the question would warrant further exploration.

Normally, many more sessions are required to produce **and maintain** improvements in behaviour with neurofeedback. Like the Scott- Kaiser study, measure of sustained attention improved quickly in this study (12-13 sessions). The assumption was that an improvement in attention would provide sufficient buffering or protection from withdrawal symptoms in order to enable the participants to reduce their smoking. Although the follow-up to the treatment was relatively short-term, it is unlikely that if participants were still smoking (albeit less) at the end of the treatment, that they would achieve abstinence without further support. It would be interesting to investigate the impact of a longer term betaSMR treatment on smoking cessation, or even the use of an alpha-theta protocol as a follow-up the betaSMR program, as was done in the Scott-Kaiser study. "The efficacy of alpha-theta EEG biofeedback may lie in its ability to allow participants to better tolerate stress, anxiety, and anxiety-eliciting situations, which are particularly evident during the initial phases of recovery. This protocol was shown to significantly lower 13 of the scales of the Millon Clinical Multiaxial Inventory (MCMI)..." (Scott et al., 2005, p. 455). This approach may prove invaluable and even necessary in resolving the problems encountered with unexpected stressors and self-efficacy questions. Individuals with ADHD are often plagued by difficulties with self-esteem and depression to a greater degree than the norm. Including more in-depth measures of these factors in the pre and post assessments would improve understanding of the impact of each protocol on participants.

Finally, all the participants were white women. It has been accepted for some time that there are gender differences in the way ADHD manifests in women and men (more anxiety, more inattention, possibly more executive functioning issues). More evidence is also accumulating

underlining how gender differences alter nicotine dependence and withdrawal symptoms as well (McClernon et al., 2011). Given the research that indicates important differences in how race and gender affect outcomes, the generalisability of the results is therefore limited.

Conclusions

Addictions have long been a particular focus of biofeedback practitioners because of the non-intrusive nature of these techniques. Side-effects are rare and short-lived if any. Clients who are already struggling to regain control of their substance use are good candidates for approaches that do not add to their physiological burden. The focus on self-regulation in biofeedbacks is inherently therapeutic for what ails them. Neurofeedback has a good track record in the treatment of alcohol and stimulant abuse. "Taken together, while current pharmacological treatments control behavioral symptoms for many individuals, there remains a significant need for new treatment strategies in ADHD, including treatments aimed at cognitive dysfunction and emotion dysregulation as these are not adequately treated with existing pharmacotherapies" (Potter et al., 2014, p. 1105).

There is an established relationship between attention problems and the abuse of stimulants such as cocaine and nicotine. People with ADHD often develop more severe addictions with these substances and have a more difficult time abstaining. Treatment options that potentially increase the side-effects suffered by this group do not contribute to better cessation outcomes. BetaSMR neurofeedback training has been used since the early days of neurofeedback to help individuals better regulate their attention. It has also been used in the past to 'prime' stimulant abusing patients prior to another neurofeedback intervention and was found to significantly contribute to their eventual freedom from addiction. It is therefore a good fit in the toolkit of practitioners looking to provide adjunct therapies to those clients who want to quit smoking.

In this multiple-baseline across participants study, four smokers with attention problems who were already using nicotine patches in unsuccessful attempts to quit smoking were provided with betaSMR neurofeedback training for thirteen sessions. It was hypothesized that improvement in their ADHD symptom status would also improve their chances at smoking cessation. Although

abstinence was achieved by only one participant, results were positive for three of the four participants who decreased significantly, if moderately, their nicotine dependency as measured by the CDS-5 and for whom there were no increases in withdrawal symptoms as measured by the CSW-21. Although the fourth participant did not decrease her dependency scores in the comparison of Phase A to Phase B of this study, she did report a reduction in number of cigarettes smoked. Finally, all the participants showed eventual significant improvements in sustained attention scores.

Neurofeedback as a treatment is based upon operant conditioning principles (Gunkelman & Johnstone, 2005). The EEG can be characterised as behaviour. Although highly technological in nature, the fundamentals of neurofeedback are based in the grassroots of clinical psychological practise. Clinical psychologists and their clients could potentially benefit enormously from this brain-based modality as part of a multi-modal approach to treatment, yet it remains largely unknown or misunderstood. Although this paper focussed on adult smokers with ADHD, there is emerging research on the use of neurofeedback for many other mental health disorders as well.

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Appendix 1
Study Timelines

STUDY TIMELINES:

Non-concurrent baselines

Daily measures

VB baseline = 20 days	**treatment starts on day 21 ends on day 56**
CR baseline = 10 days	**treatment starts on day 11 ends on day 50**
JW baseline = 8 days	**treatment starts on day 9 ends on day 36**
MT baseline = 7 days	**treatment starts on day 8 ends on day 40**

VB i b b b b b b b b b b b b b b b b b b b /n t n t t t t n t n t n t t n t n t t t t t n t n t t n t n t n t t t t n

CR i b b b b b b b b b b /n t n t n t t n t n t t t t t n t t n t t t n t t n t t t t t n t n t t n t t t n

JW i b b b b b b b b/ n t n t t n t n t n t n t t n t n t t n t t n t n t t n

MT i b b b b b b b b/ n t n t n t t n t n t n t t t t t t n t n t t n t n t t n t n t n

i = first cpt; b = day of baseline phase; / = start of treatment phase and t= day of treatment phase; n = day of neurofeedback treatment; n = day of neurofeedback treatment *and* cpt measure

CDS and CWS measures every day during both phases

Appendix 2
Fagerström Test for Nicotine Dependence (FTND)

Fagerström Test for Nicotine Dependence (FTND)

Question	Answers	Points
1. How soon after you wake up do you smoke your first cigarette?	Within 5 minutes	3
	6-30 mins	2
	31-60 mins	1
	> 60 mins	0
2. Do you find it difficult to refrain from smoking in places where it is forbidden, e.g., in church, at the library, in the cinema, at work, etc.?	Yes	1
	No	0
3. Which cigarette would you most hate to give up?	The first one in the morning	1
	Any other	0
4. How many cigarettes/day do you smoke?	10 or less	0
	11-20	1
	21-30	2
	31 or more	3
5. Do you smoke more frequently during the first hours after waking than during the rest of the day?	Yes	1
	No	0
6. Do you smoke if you are so ill that you are in bed most of the day?	Yes	1
	No	0

Appendix 3
Adult Self-Report Scale Screener (ASRS v 1.1)
ASRS-6 and ASRS-18

Are you living with Adult ADHD?

The questions below can help you find out.

Many adults have been living with Adult Attention-Deficit/Hyperactivity Disorder (Adult ADHD) and don't recognize it. Why? Because its symptoms are often mistaken for a stressful life.

The following questionnaire can be used as a starting point to help you recognize the signs/symptoms of Adult ADHD but is not meant to replace consultation with a trained healthcare professional. **An accurate diagnosis can only be made through a clinical evaluation.** Regardless of the questionnaire results, if you have concerns about diagnosis and treatment of Adult ADHD, please discuss your concerns with your physician.

This Adult Self-Report Scale (ASRS) Screener is intended for people aged 18 years or older.

Adult Self-Report Scale (ASRS) Screener

Name **Date**

Circle the number that best describes how you have felt and conducted yourself over the past 6 months. Please give the completed questionnaire to your healthcare professional during your next appointment to discuss the results.	Never	Rarely	Sometimes	Often	Very Often	Score
1. How often do you have difficulty getting things in order when you have to do a task that requires organization?	0	1	2	3	4	
2. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?	0	1	2	3	4	
3. How often are you distracted by activity or noise around you?	0	1	2	3	4	
4. How often do you leave your seat in meetings or other situations in which you are expected to remain seated?	0	1	2	3	4	
5. How often do you feel restless or fidgety?	0	1	2	3	4	
6. How often do you have difficulty waiting your turn in situations when turn taking is required?	0	1	2	3	4	
A score of 11 points or higher indicates that your symptoms may be consistent with Adult ADHD. It may be beneficial for you to talk with your healthcare provider about an evaluation.				**Total**		

The 6-question Adult Self-Report Scale (ASRS) Screener is a subset of the WHO's 18-question Adult ADHD Self-Report Scale (Adult ASRS) Symptom Checklist.

CADDRA
CANADIAN ADHD RESOURCE ALLIANCE

Patient Name:
Date of Birth: MRN/File No:
Physician Name: Date:

ADULT ADHD SELF-REPORT SCALE (ASRS-V1.1) SYMPTOM CHECKLIST

Please answer the questions below, rating yourself on each of the criteria shown using the scale on the right side of the page. As you answer each question, place an X in the box that best describes how you have felt and conducted yourself over the past 6 months. Please give this completed checklist to your healthcare professional to discuss during your appointment.	Never	Rarely	Sometimes	Often	Very often
PART A					
1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?					
2. How often do you have difficulty getting things in order when you have to do a task that requires organization?					
3. How often do you have problems remembering appointments or obligations?					
4. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?					
5. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?					
6. How often do you feel overly active and compelled to do things, like you were driven by a motor?					
PART B					
7. How often do you make careless mistakes when you have to work on a boring or difficult project?					
8. How often do you have difficulty keeping your attention when you are doing boring or repetitive work?					
9. How often do you have difficulty concentrating on what people say to you, even when they are speaking to you directly?					
10. How often do you misplace or have difficulty finding things at home or at work?					
11. How often are you distracted by activity or noise around you?					
12. How often do you leave your seat in meetings or in other situations in which you are expected to stay seated?					
13. How often do you feel restless or fidgety?					
14. How often do you have difficulty unwinding and relaxing when you have time to yourself?					
15. How often do you find yourself talking too much when you are in social situations?					
16. When you're in a conversation, how often do you find yourself finishing the sentences of the people you are talking to, before they can finish it themselves?					
17. How often do you have difficulty waiting your turn in situations when turn taking is required?					
18. How often do you interrupt others when they are busy?					

Appendix 4
CADDRA ADHD Assessment Toolkit (CAAT)

CADDRA
CANADIAN ADHD RESOURCE ALLIANCE

Patient Name:	
Date of Birth:	MRN/File No:
Physician Name:	Date:

Weiss Symptom Record (WSR)

Instructions to Informant: Check the box that best describes typical behavior *Instructions to Physician: Symptoms rated 2 or 3 are positive and total count completed below*	Not at all (0)	Somewhat (1)	Pretty much (2)	Very much (3)	N/A	# Items scored 2 or 3 (DSM Criteria)
ADHD COMBINED TYPE 314.01						≥6/9 IA & HI
ATTENTION 314.00						
Fails to give close attention to details, careless mistakes						
Difficulty sustaining attention in tasks or fun activities						
Does not seem to listen when spoken to directly						
Does not follow through on instructions and fails to finish work						
Difficulting organizing tasks and activities						
Avoids tasks that require sustained mental effort (boring)						
Losing things						
Easily distracted						
Forgetful in daily activities						/9 (≥6/9)
HYPERACTIVE/IMPULSIVE 314.01						
Fidgety or squirms in seat						
Leaves seat when sitting is expected						
Feels restless						
Difficulty in doing fun things quietly						
Always on the go or acts as if "driven by a motor"						
Talks excessively						
Blurts answers before questions have been completed						
Difficulty awaiting turn						
Interrupting or intruding on others						/9 (≥6/9)
OPPOSITIONAL DEFIANT DISORDER 313.81						
Loses temper						
Argues with adults						
Actively defies or refuses to comply with requests or rules						
Deliberately annoys people						
Blames others for his or her mistakes or misbehaviour						
Touchy or easily annoyed by others						
Angry or resentful						
Spiteful or vindictive						/8 (≥4/8)

	Not at all (0)	Somewhat (1)	Pretty much (2)	Very much (3)	N/A	Diagnoses
CONDUCT DISORDER 312.8						**SEVERITY**
Bullies, threatens, or intimidates others						
Initiates physical fights						
Has used a weapon (bat, brick, bottle, knife, gun)						
Physically cruel to people						
Physically cruel to animals						
Stolen while confronting a victim						
Forced someone into sexual activity						
Fire setting with the intent of damage						
Deliberately destroyed others' property						
Broken into a house, building, or car						
Often lies to obtain goods or benefits or avoid obligations						
Stealing items of nontrivial value without confronting victim						
Stays out at night despite prohibitions						
Run away from home overnight at least twice						
Truant from school						/15(≥3/15)
ANXIETY						
Worries about health, loved ones, catastrophe						300.02
Unable to relax; nervous						300.81
Chronic unexplained aches and pains						300.30
Repetitive thoughts that make no sense						
Repetitive rituals						300.01
Sudden panic attacks with intense anxiety						300.23
Excessively shy						
Refusal to do things in front of others						309.21
Refusal to go to school, work or separate from others						300.29
Unreasonable fears that interfere with activities						312.39
Pulls out hair, eyebrows						
Nail biting, picking						
Refusal to talk in public, but talks at home						mutism
DEPRESSION 296.2 (single) .3 (recurrent)						
Has been feeling sad, unhappy or depressed	Yes		No	Must be present		
No interest or pleasure in life	Yes		No	Must be present		
Feels worthless						
Has decreased energy and less productive						
Hopeless and pessimistic about the future						
Excessive feelings of guilt or self blame						
Self-injurious or suicidal thoughts						
Social withdrawal						
Weight loss or weight gain						
Change in sleep patterns						≥5/9>2wks

	Not at all (0)	Somewhat (1)	Pretty much (2)	Very much (3)	N/A	Diagnoses
DEPRESSION (CONT'D)						**SEVERITY**
Agitated or sluggish, slowed down						
Decreased concentration or indecisiveness						
Past suicide attempts	#		Serious			
MANIA 296.0(manic) .6(mixes) .5(depressed)						
Distinct period of consistent elevated or irritable mood		Yes	No		Must be present	
Grandiose, sudden increase in self esteem						
Decreased need for sleep						
Racing thoughts						
Too talkative and speech seems pressured						
Sudden increase in goal directed activity, agitated						≥3 >1wk
High risk activities (spending money, promiscuity)						/3 (≥3)
SOCIAL SKILLS 299						
Makes poor eye contact or unusual body language						
Failure to make peer relationships						
Lack of spontaneous sharing of enjoyment						
Lacks reciprocity or sensitivity to emotional needs of others						
Language delay or lack of language communication						
Difficulty communicating, conversing with others						
Speaks in an odd, idiosyncratic or monotonous speech						
Lack of creative, imaginative play or social imitation						
Intensely fixated on one particular interest						
Rigid sticking to nonfunctional routines or rituals						
Preoccupied with objects and parts of objects						
Repetitive motor mannerisms (hand flapping, spinning)						
PSYCHOSIS 295						
Has disorganized, illogical thoughts						
Hears voices or sees things						
Conviction that others are against or will hurt them						
People can read their thoughts, or vice versa						
Belief that the television is talking specifically to them						
A fixed belief that is out of touch with reality						
Thought sequence does not make sense						
SUBSTANCE ABUSE						
Excessive alcohol (> 2 drinks/day, > 4 drinks at once)						305
Smokes cigarettes						
Daily marijuana use						
Use of any other street drugs						
Abuse of prescription drugs						

	Not at all (0)	Somewhat (1)	Pretty much (2)	Very much (3)	N/A	Diagnoses
SLEEP DISORDERS 307.4						**SEVERITY**
Agitated or sluggish, slowed down						
Has difficulty falling asleep						
Has difficulty staying asleep						
Has abnormal sleep patterns during the day						347
Unanticipated falling asleep during the day						307.4
Sleep walking						307.4
Has nightmares						307.45
Falls asleep late and sleeps in late						3.27
Sleep schedule changes from day to day						
Excessive snoring						
A feeling of restless legs while trying to sleep						
Observed to have sudden kicking while asleep						780.57
Observed to have difficulty breathing at night						
ELIMINATION DISORDERS 307						
Wets the bed at night						
Wets during the day						
Soils self						
EATING DISORDERS 307						
Vomits after meals or binging						
Underweight and refuses to eat						307.1
Distorted body image						
Picky eater						
High junk food diet						
LEARNING DISABILITIES 315						
Delayed expressive language						
Stuttering						
Problems articulating words						315
Below grade level in reading						315.1
Below grade level in math						315.2
Trouble with writing (messy, tiring, avoids writing)						
Variable performance in school						
Underachieves at school relative to potential						315.4
DEVELOPMENTAL COORDINATION DISORDER						
Difficulty with gross motor skills (i.e. gym, sports, biking)						
Clumsy						
Difficulty with fine motor (buttons, shoe laces, cutting)						

	Not at all (0)	Somewhat (1)	Pretty much (2)	Very much (3)	N/A	Diagnoses
PERSONALITY 301						**SEVERITY**
Unstable interpersonal relationships						
Frantic efforts to avoid abandonment						
Recurrent suicidal ideation or attempts						
Intense anger						
Major mood swings						BPD 301.83
Impulsive self destructive or self injurious behavior						
Fragile identity or self image						
Chronic feelings of emptiness						
Transient stress related dissociation or paranoia						/9 (≥5/9)
Self centred or entitled						NPD 301.81
Deceitful, aggressive, or lack of remorse						ASP 301.7
COMMENTS:						

ADHD=attention deficit hyperactivity disorder; IA=inattentive subtype; HI=hyperactive impulsive subtype; BPD=borderline personality disorder; NPD=narcissistic personality disorder; ASP=antisocial personality disorder.

CADDRA
CANADIAN ADHD RESOURCE ALLIANCE

Patient Name:
Date of Birth: MRN/File No:
Physician Name: Date:

WEISS FUNCTIONAL IMPAIRMENT RATING SCALE – SELF REPORT (WFIRS-S)

Name: _____ Date: DD MM YY

Date of birth: DD MM YY Sex: ☐ Male ☐ Female
Work: ☐ Full time ☐ Part time ☐ Other _____
School: ☐ Full time ☐ Part time

Circle the number for the rating that best describes how your emotional or behavioural problems have affected each item in the last month.

		Never or not at all	Sometimes or somewhat	Often or much	Very often or very much	n/a
A	**FAMILY**					
1	Having problems with family	0	1	2	3	n/a
2	Having problems with spouse/partner	0	1	2	3	n/a
3	Relying on others to do things for you	0	1	2	3	n/a
4	Causing fighting in the family	0	1	2	3	n/a
5	Makes it hard for the family to have fun together	0	1	2	3	n/a
6	Problems taking care of your family	0	1	2	3	n/a
7	Problems balancing your needs against those of your family	0	1	2	3	n/
8	Problems losing control with family	0	1	2	3	n/a
B	**WORK**					
1	Problems performing required duties	0	1	2	3	n/a
2	Problems with getting your work done efficiently	0	1	2	3	n/a
3	Problems with your supervisor	0	1	2	3	n/a
4	Problems keeping a job	0	1	2	3	n/a
5	Getting fired from work	0	1	2	3	n/a
6	Problems working in a team	0	1	2	3	n/a
7	Problems with your attendance	0	1	2	3	n/a
8	Problems with being late	0	1	2	3	n/a
9	Problems taking on new tasks	0	1	2	3	n/a
10	Problems working to your potential	0	1	2	3	n/a
11	Poor performance evaluations	0	1	2	3	n/a

		Never or not at all	Sometimes or somewhat	Often or much	Very often or very much	n/a
4	Problems getting ready for bed	0	1	2	3	n/a
5	Problems with eating (picky eater, junk food)	0	1	2	3	n/a
6	Problems with sleeping	0	1	2	3	n/a
7	Gets hurt or injured	0	1	2	3	n/a
8	Avoids exercise	0	1	2	3	n/a
9	Needs more medical care	0	1	2	3	n/a
10	Has trouble taking medication, getting needles or visiting the doctor/dentist	0	1	2	3	n/a
D	**CHILD'S SELF-CONCEPT**					
1	My child feels bad about himself/herself	0	1	2	3	n/a
2	My child does not have enough fun	0	1	2	3	n/a
3	My child is not happy with his/her life	0	1	2	3	n/a
E	**SOCIAL ACTIVITIES**					
1	Being teased or bullied by other children	0	1	2	3	n/a
2	Teases or bullies other children	0	1	2	3	n/a
3	Problems getting along with other children	0	1	2	3	n/a
4	Problems participating in after-school activities (sports, music, clubs)	0	1	2	3	n/a
5	Problems making new friends	0	1	2	3	n/a
6	Problems keeping friends	0	1	2	3	n/a
7	Difficulty with parties (not invited, avoids them, misbehaves)	0	1	2	3	n/a
F	**RISKY ACTIVITIES**					
1	Easily led by other children (peer pressure)	0	1	2	3	n/a
2	Breaking or damaging things	0	1	2	3	n/a
3	Doing things that are illegal	0	1	2	3	n/a
4	Being involved with the police	0	1	2	3	n/a
5	Smoking cigarettes	0	1	2	3	n/a
6	Taking illegal drugs	0	1	2	3	n/a
7	Doing dangerous things	0	1	2	3	n/a
8	Causes injury to others	0	1	2	3	n/a
9	Says mean or inappropriate things	0	1	2	3	n/a
10	Sexually inappropriate behaviour	0	1	2	3	n/a

SCORING:

1. Number of items scored 2 or 3
   or
2. Total score
   or
3. Mean score

DO NOT WRITE IN THIS AREA

A. Family	
B. School	
Learning	
Behaviour	
C. Life skills	
D. Child's self-concept	
E. Social activities	
F. Risky activities	
Total	

Appendix 5
Wender Utah Rating Scale

WENDER UTAH RATING SCALE (WURS)

PATIENT'S INIALS _____ PATIENT'S NUMBER _____ DATE _____ M.D.'S INITIALS _____

As a child I was (or had):	Not at all or very slightly	Mildly	Moderately	Quite a bit	Very much
I. Active, restless, always on the go					
2. Afraid of things					
3. Concentration problems, easily distracted					
4. Anxious, worrying					
S. Nervous, fidgety					
6. Inattentive, daydreaming					
7. Hot- or short-tempered, low boiling point					
8. Shy, sensitive					
9. Temper outbursts, tantrums					
10. Trouble with stick-to-it-tiveness, not following through, failing to finish things started					
11. Stubborn, strong-willed					
12. Sad or blue, depressed, unhappy					
13. Incautious, dare-devilish, involved in pranks					
14. Not getting a kick out of things, dissatisfied with life					
15. Disobedient with parents, rebellious, sassy					
16. Low opinion of myself					
18. Outgoing, friendly, enioyed company of people					
19. Sloppy, disorganized					
20. Moody, ups and downs					
21. Angry					
22. Friends, popular					
23. Well-organized, tidy, neat					
24. Acting without thinking, impulsive					
25. Tendency to be immature					
26. Guilty feelings, regretful					
27. Losing control of myself					
28. Tendency to be or act irrational					
29. Unpopular with other children, didn't keep friends for long, didn't get along with other children					
30. Poorly coordinated, did not participate in sports					
31. Afraid of losing control of self					
32. Well-coordinated, picked first in games					
33. Tomboyish (for women only)					
34. Running away from home					
35. Getting into fights					
36. Teasing other children					
37. Leader bossy					
38. Difficulty getting awake					
39. Follower, led around too much					
40. Trouble seeing things from someone else's point of view					
41. Trouble with authorities, trouble with school, visits to principal's office					
42. Trouble with police, booked, convicted					
Medical problems as a child:					
43. Headaches					
44. Stomachaches					
45. Constipation					

WENDER UTAH RATING SCALE (WURS), CONTINUED

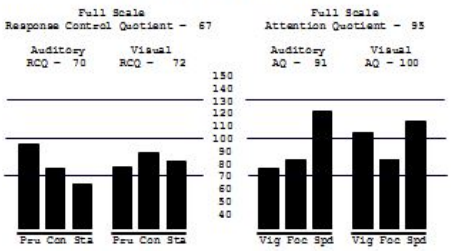
Medical problems as a child (continued):	Not at all or very slightly	Mildly	Moderately	Quite a bit	Very much
46. Diarrhea					
47. Food allergies					
48. Other allergies					
49. Bedwetting					
As a child in school, I was (or had):					
50. Overallagiodstudent, fast					
51. Overall a poor student, slow learner					
52. Slow in learning to read					
53. Slow reader					
54. Trouble reversing letters					
55. Problems with spelling					
56. Trouble with mathematics or numbers					
57. Bad handwriting					
58. Able to read pretty well but never really enjoyed reading					
59. Not achievingup to potential					
60. Repeating grades (which grades?)					
61. Suspended or expelled (which grades?)					

Appendix 6
IVA+Plus Sample Report

IVA+Plus Standard Scales Analysis

Full Scale
Response Control Quotient = 67

Full Scale
Attention Quotient = 95



Auditory Response Validity Check = Valid
Visual Response Validity Check = Valid

Fine Motor Hyperactivity: None Mild Mod Sev Ext

PERSONAL INFORMATION

Last Name F. First Name

Social Security # Educational Level

Date of Birth (MM-DD-YYYY) 04/01/1956 Age 54 years

Sex (M/F) F On medication (Y/N)Y

Diagnosis 1 (ICD code) Medication A
Diagnosis 2 (ICD code) Medication B
Diagnosis 3 (ICD code) Medication C

Test Version 2010.12 TEST INFORMATION

Group Code ID Code Examiner Code

Date 11/26/2010 11:12AM Note

Comment

. 11/26/2010 11:12AM

RESPONSE CONTROL

Auditory Raw	Auditory Quotient	Primary Scales	Visual Quotient	Visual Raw
97.3%	95	Prudence	77	93.8%
71.9%	76	Consistency	89	75.1%
83.5%	64	Stamina	82	88.0%
Hyperactive Events: 4		Fine Motor Reg. Quot: 101		

ATTENTION

Auditory Raw	Auditory Quotient	Primary Scales	Visual Quotient	Visual Raw
95.6%	76	Vigilance	105	100.0%
72.5%	83	Focus	83	73.9%
536ms	121	Speed	113	399ms

Attribute		Raw	Q	<----+----+----+----o----+----+----+---->
Balance		74.5%	104	Vis Dom No Bias Aud Dom
Readiness	A	88.0%	83	A
	V	83.3%	80	V High No Bias Low

Symptomatic		Raw	Q	WNL Mild Mod Sev Ext
Comprehension	A	99.2%	102	A
	V	100.0%	106	
Persistence	A	94.4%	99	A
	V	102.0%	105	
Sensory/Motor	A	173ms	130	A
	V	234ms	107	

Norms: IVA+Plus 2004.1 03-14-2001 for F age 45 - 54

11/26/2010 11:12AM IVA+Plus

SUSTAINED ATTENTION SCALES

These two additional scales are provided for use with the IVA+Plus Interpretive Flowchart for ADHD.

Sustained Auditory Attention Quotient	87
Sustained Visual Attention Quotient	103

Quotient scores which are between zero and 59 reflect extreme deficits.

Appendix 7
Cigarette Dependence Scale (CDS-12/CDS-5)

The Cigarette Dependence Scale, English-language version **DATE**_____

Questions	Response options	Coding
1. Please rate your addiction to cigarettes on a scale of 0 to 100: -I am NOT addicted to cigarettes at all = 0 -I am extremely addicted to cigarettes = 100	___Addiction	0-20 = 1 21-40 = 2 41-60 = 3 61-80 = 4 81-100 = 5
2. On average, how many cigarettes do you smoke per day?	___Cigarettes/day	0-5 = 1 6-10 = 2 11-20 = 3 21-29 = 4 30+ = 5
3. Usually, how soon after waking up do you smoke your first cigarette?	___Minutes	0-5 = 5 6-15 = 4 16-30 = 3 31-60 = 2 61+ = 1
4. For you, quitting smoking for good would be:		Impossible = 5 Very difficult = 4 Fairly difficult = 3 Fairly easy = 2 Very easy = 1

Please indicate whether you agree with each of the following statements:

5. After a few hours without smoking I feel an irresistible urge to smoke.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

6. The idea of not having any cigarettes causes me stress.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

7. Before going out I make sure that I always have cigarettes with me.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

8. I am a prisoner of cigarettes.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

9. I smoke too much.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

10. Sometimes I drop everything to go out and buy cigarettes.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

11. I smoke all the time.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

12. I smoke despite the risks to my health.
Totally disagree = 1/Somewhat disagree = 2/Neither agree nor disagree = 3/Somewhat agree = 4/Fully agree = 5

Appendix 8
Cigarette Withdrawal Scale (CWS-21)

Cigarette Withdrawal Scale (CWS-21) **Date :**

Response options	
totally disagree	=1
mostly disagree	=2
more or less agree	=3
mostly agree	=4
totally agree	=5

1. I feel depressed
2. My morale is low
3. I feel worried
4. I feel anxious
5. The only thing I can think about is smoking a cigarette
6. I miss cigarettes terribly
7. I feel an irresistible need to smoke
8. I would like to hold a cigarette between my fingers
9. I am irritable
10. I get angry easily
11. I have no patience
12. I feel nervous
13. I find it difficult to think clearly
14. I find it hard to concentrate
15. I find it hard to focus on the task at hand
16. I am eating more than usual
17. My appetite has increased
18. I have put on weight recently
19. I have difficulty sleeping
20. I wake up often during the night
21. I have trouble falling asleep at night

Appendix 9
IVA+Plus Results

VB

Day	Evaluation	28*	35	44	51*	56
RC-Quotient	31	-	76	70	-	63
RC-Auditory	55	-	84	68	-	66
RC-Visual	35	-	78	86	-	76
Att-Quotient	33	-	41	64	-	81
Att-Auditory	68	-	48	63	-	97
Att-Visual	8	-	48	74	-	67
Sus-Att-Aud	12	-	38	43	-	95
Sus-Att-Vis	14	-	50	49	-	61

CR

Day	Evaluation	15	26	33	41	50
RC-Quotient	49	35	30	44	28	55
RC-Auditory	62	45	32	57	40	78
RC-Visual	47	39	43	42	32	38
Att-Quotient	83	106	105	96	95	108
Att-Auditory	92	107	103	104	92	105
Att-Visual	77	104	106	89	98	110
Sus-Att-Aud	69	69	72	75	74	107
Sus-Att-Vis	69	79	88	61	109	111

JW

Day	Evaluation	14	20	28*	31	36
RC-Quotient	13	#	31	-	62	98
RC-Auditory	24	#	38	-	67	108
RC-Visual	21	#	38	-	66	76
Att-Quotient	71	#	87	-	68	81
Att-Auditory	74	#	86	-	78	83
Att-Visual	72	#	88	-	63	81
Sus-Att-Aud	66	#	94	-	66	73
Sus-Att-Vis	64	#	77	-	50	83

MT

Day	Evaluation	12	19	31	40
RC-Quotient	112	84	103	97	105
RC-Auditory	130	117	101	118	109
RC-Visual	124	100	103	109	108
Att-Quotient	86	41	67	70	109
Att-Auditory	82	23	48	51	81
Att-Visual	82	24	52	55	93
Sus-Att-Aud	77	@	37	22	112
Sus-Att-Vis	90	@	20	33	90

(*apt.missed), (@ =invalid), (# = data lost)

Appendix 10
Consent Form

FORMULAIRE D'INFORMATION ET DE CONSENTEMENT

Vous êtes invité(e) à participer à un projet de recherche. Le présent document vous renseigne sur les modalités de ce projet de recherche. S'il y a des mots ou des paragraphes que vous ne comprenez pas, n'hésitez pas à poser des questions. Pour participer à ce projet de recherche, vous devrez signer le consentement à la fin de ce document et nous vous en remettrons une copie signée et datée.

Titre du projet

Traiter la dépendance à la nicotine par le neurofeedback chez des adultes ayant un trouble déficitaire de l'attention avec hyperactivité.

Personnes responsables du projet

Chercheure principale : Suzanne Lamontagne est psychologue en pratique privée et étudiante au doctorat en psychologie à l'Université de Sherbrooke. On peut la rejoindre par courriel à …Le présent projet de recherche s'inscrit dans le cadre de sa thèse de doctorat en psychologie clinique.
Ce projet est réalisé sous la direction de Dre Dominique Lorrain, professeure titulaire au Département de psychologie de l'Université de Sherbrooke et directrice du Laboratoire de vigilance au Centre de recherche sur le vieillissement du Centre de santé et de services sociaux – Institut universitaire de gériatrie de Sherbrooke . On peut la rejoindre par courriel à …

Objectifs du projet

L'étude consiste à évaluer l'impact d'un entraînement en neurofeedback chez des adultes atteints d'un TDA/H et qui, malgré l'utilisation d'un timbre de nicotine, n'arrivent toujours pas à cesser de fumer. Ce traitement non invasif utilise l'activité du cerveau comme rétroaction pour aider à développer un meilleur contrôle attentionnel.

Raison et nature de la participation

Dans le cadre de ce projet, nous procéderons à une évaluation des symptômes typiquement associés au TDA/H. Cette évaluation se fera en deux parties. La première partie sera une rencontre d'environ trois heures, Des pauses vous seront proposées afin d'éviter la fatigue. Au cours de cette rencontre vous passerez des tests cognitifs qui nous permettront de mieux connaître votre profil attentionnel. Je vous remettrai également des questionnaires que vous pourrez compléter à la maison et qui nous permettrons d'évaluer la présence de problèmes qui sont fréquemment retrouvés dans le TDA/H. Il y aura à la fin de cette rencontre une démonstration d'un entraînement en neurofeedback.
La deuxième partie de l'évaluation sera une rencontre d'environ une heure et demie au cours de laquelle nous ferons une évaluation de votre activité cérébrale. Pour ce faire, nous placerons des électrodes (petits disques de métal maintenues en place par une pâte adhésive) à deux endroits sur votre tête ainsi que sur les lobes d'oreilles. Nous pourrons ainsi enregistrer l'activité

électrique de votre cerveau et déterminer les ondes cérébrales sur lesquelles nous travaillerons pour tenter d'améliorer vos capacités attentionnelles.

Vous serez ensuite invité à participer à une série de 10 à 20 séances de neurofeedback à raison de trois (3) fois par semaine. À chaque séance d'entrainement, nous installerons sur votre tête les électrodes de la même manière qu'au cours de l'évaluation.

Pendant la période d'entraînement, vous aurez à compléter quotidiennement deux petits questionnaires sur vos symptômes de sevrage et votre utilisation de la cigarette. Il y aura également la passation d'test d'attention sur ordinateur à chaque semaine pour mesurer des changements potentiels. Les traitements prendront fin après 20 rencontres ou avant si cette mesure indique que votre attention s'est améliorée. Dix semaines après le dernier traitement, vous serez recontacté par téléphone pour évaluer votre abstinence par rapport à la cigarette. L'évaluation ainsi que l'ensemble des traitements seront gratuits.

Toutes les rencontres auront lieu dans la ville de Pointe Claire.

Avantages pouvant découler de la participation

Votre participation à ce projet de recherche vous apportera l'avantage d'une évaluation pour le TDA/H et d'un traitement qui pourrait potentiellement aider à améliorer vos capacités attentionnelles. À cela s'ajoute le fait que cette étude contribuera à l'avancement des connaissances concernant le TDA/H et le tabagisme.

Inconvénients et risques pouvant découler de la participation

Votre participation à la recherche vous demandera une implication importante pour l'entraînement en neurofeedback. Pour atténuer les inconvénients de cette implication, des rendez-vous seront possibles jour ou soir, en semaine et en fin de semaine. Si pendant l'entraînement ou l'analyse de l'activité cérébrale vous vivez de l'inconfort ou de la fatigue, ceci devrait être que passager et vous pourrez demander de prendre une pause. À la connaissance de la chercheuse, il n'y a aucun risque associé à la participation, incluant l'usage des électrodes pour enregistrer l'activité cérébrale. L'utilisation d'une pâte adhésive pour la pose des électrodes peut toutefois légèrement défaire votre coiffure.

Droit de retrait sans préjudice de la participation

Il est entendu que votre participation à ce projet de recherche est tout à fait volontaire et que vous restez libre, à tout moment, de mettre fin à votre participation sans avoir à motiver votre décision ni à subir de préjudice de quelque nature que ce soit.

> Advenant que vous vous retiriez de l'étude, demandez-vous que les tests, les enregistrements de votre EEG et les documents vous concernant soient détruits?
> Oui ❒ Non ❒

Il vous sera toujours possible de revenir sur votre décision. Le cas échéant, la chercheuse vous demandera explicitement si vous désirez la modifier.

Confidentialité, partage, surveillance et publications

Durant votre participation à ce projet de recherche, la chercheuse responsable recueillera et consignera dans un dossier de recherche les renseignements vous concernant. Seuls les renseignements nécessaires à la bonne conduite du projet de recherche seront recueillis. Ils peuvent comprendre les informations suivantes : nom, sexe, date de naissance, les résultats de l'évaluation cognitive, les résultats de l'entraînement en neurofeedback ainsi que les autres mesures exigées lors de ce projet.

Tous les renseignements recueillis au cours du projet de recherche demeureront strictement confidentiels dans les limites prévues par la loi. Afin de préserver votre identité et la confidentialité de ces renseignements, vous ne serez identifié(e) que par un numéro de code. La clé du code reliant votre nom à votre dossier de recherche sera conservé par la chercheuse responsable du projet de recherche.

La chercheuse principale de l'étude utilisera les données à des fins de recherche dans le but de répondre aux objectifs scientifiques du projet de recherche décrits dans ce formulaire d'information et de consentement.

Les données du projet de recherche pourront être publiées dans des revues scientifiques ou partagées avec d'autres personnes lors de discussions scientifiques. Aucune publication ou communication scientifique ne renfermera d'information permettant de vous identifier. Les données recueillies seront conservées, sous clé, pour une période n'excédant pas 5 ans après la fin de la collecte des données. Après cette période, les données seront détruites.

À des fins de surveillance et de contrôle, votre dossier de recherche pourrait être consulté par une personne mandatée par le Comité d'éthique de la recherche Lettres et sciences humaines, ou par des organismes gouvernementaux mandatés par la loi. Toutes ces personnes et ces organismes adhèrent à une politique de confidentialité.

Résultats de la recherche et publication

Vous serez informé des résultats de la recherche et des publications qui en découleront, le cas échéant. Nous préserverons l'anonymat des personnes ayant participé à l'étude.

Surveillance des aspects éthiques et identification du président du Comité d'éthique de la recherche Lettres et sciences humaines

Le Comité d'éthique de la recherche Lettres et sciences humaines a approuvé ce projet de recherche et en assure le suivi. De plus, il approuvera au préalable toute révision et toute modification apportée au formulaire d'information et de consentement, ainsi qu'au protocole de recherche.

Vous pouvez parler de tout problème éthique concernant les conditions dans lesquelles se déroule votre participation à ce projet avec la responsable du projet ou expliquer vos préoccupations**,** président par intérim du Comité d'éthique de la recherche Lettres et sciences humaines, en communiquant par l'intermédiaire de son secrétariat au numéro suivant :

Consentement libre et éclairé

Je, _____ (*nom en caractères d'imprimerie)*, déclare avoir lu et/ou compris le présent formulaire et j'en ai reçu un exemplaire. Je comprends la nature et le motif de ma participation au projet. J'ai eu l'occasion de poser des questions auxquelles on a répondu, à ma satisfaction.
Par la présente, j'accepte librement de participer au projet.

Signature de la participante ou du participant : _____

Fait à _____ , le _____201_.

Déclaration de responsabilité des chercheurs de l'étude

Je, _____ chercheuse principale de l'étude, déclare que je suis responsable du déroulement du présent projet de recherche. Je m'engage à respecter les obligations énoncées dans ce document et également à vous informer de tout élément qui serait susceptible de modifier la nature de votre consentement.

Je certifie également avoir expliqué à la participante ou au participant intéressé(e) les termes du présent formulaire, avoir répondu aux questions qu'il ou qu'elle m'a posées à cet égard et lui avoir clairement indiqué qu'il ou qu'elle reste, à tout moment, libre de mettre un terme à sa participation au projet de recherche décrit ci-dessus. Je m'engage à garantir le respect des objectifs de l'étude et à respecter la confidentialité.

Signature : _____

Appendix 11
Recruitment Letter

Une alternative pour les patient(e)s avec un TDAH qui utilisent sans succès un timbre de nicotine...

Docteur,
Mon nom est Suzanne Lamontagne, psychologue oeuvrant au sein de la communauté de l'Ouest de l'Île depuis plus de 15 ans. Dans le cadre de mon projet de thèse en vue d'obtenir un doctorat en psychologie clinique, je mène une étude qui a pour but d'évaluer l'efficacité potentielle d'un traitement de neurofeedback chez des adultes atteints d'un déficit d'attention (TDAH) qui utilisent un timbre de nicotine, sans réussir à cesser de fumer.

Il est connu que les adultes atteints d'un trouble attentionnel ont des symptômes de sevrage importants et ont beaucoup de difficulté à cesser de fumer, malgré l'utilisation d'un timbre de nicotine. Bien que les psychostimulants soient le traitement pharmacologique de choix pour le TDAH, les effets secondaires indésirables qu'ils procurent en réduisent considérablement leurs utilisations chez ceux qui veulent cesser de fumer, surtout lorsqu'ils s'ajoutent à des substances ayant déjà des propriétés stimulantes, comme la nicotine. Le neurofeedback qui est une intervention thérapeutique reconnu comme étant efficace dans le traitement du TDAH pourrait également contrer les symptômes de sevrage et ainsi augmenter les chances de succès avec un timbre de nicotine.

Je vous invite donc à me référer vos patients ou patientes présentant un tel profil. J'évaluerai leur cas selon les critères du CADDRA combiné à des mesures cognitives. J'offrirai gratuitement aux personnes admissibles un traitement en neurofeedback à mon bureau, dans la ville de Pointe-Claire. Ces personnes devront participer à 3 rencontres par semaine, pour une durée de 3 à 5 semaines.

Les critères d'exclusion comprendront un traitement pharmacologique pour le TDAH, la présence d'une maladie psychiatrique ou neurologique, la toxicomanie ou un traitement antérieur en neurofeedback.

Si vous désirez obtenir plus d'information sur le neurofeedback, il me fera grand plaisir d'en discuter avec vous. Vous pouvez également consulter le site du *International Society for Neurofeedback Research* au www.isnr.org pour apprécier les avantages de la neurothérapie.

Le projet de recherche a été approuvé par le Comité d'éthique de la recherche Lettres et Sciences Humaines de l'Université de Sherbrooke et sera supervisé par Docteur Dominique Lorrain, Ph.D., psychologue et professeure titulaire au département de psychologie de l'Université de Sherbrooke et chercheure au Centre de recherche sur le vieillissement du Centre de santé et de services sociaux - Institut universitaire de gériatrie de Sherbrooke.

Je vous remercie de votre attention et vous prie d'agréer l'expression de mes sentiments distingués.

Appendix 12

Neurofeedback and qEEG Descriptions

QU'EST-CE QUE LE NEUROFEEDBACK ?

Le neurofeedback est un biofeedback qui permet l'entraînement des ondes cérébrales pour améliorer certaines capacités cognitives tel que l'attention. Le biofeedback est une technique permettant d'apprendre à contrôler des fonctions physiques et mentales qui ne peuvent être ressenties ou influencées consciemment car elles sont gérées automatiquement. Cette méthode d'autorégulation par l'utilisation d'appareils (électroniques ou informatiques) favorise l'observation et la **modulation volontaire** des fonctions du corps. Les appareils captent et amplifient l'information (température corporelle, rythme cardiaque, activité musculaire, ondes cérébrales, etc.) et les traduisent en signaux auditifs ou visuels. Le patient peut graduellement apprendre quels types de respiration, quelles pensées, quelles postures et quelles attitudes lui procurent les meilleurs résultats.

Dans le cas du neurofeedback, l'électroencéphalographe (EEG) est l'appareil qui capte les ondes du cerveau. Des capteurs/électrodes posés sur le cuir chevelu digitalisent les courants neuroélectriques du cerveau et les envoient à un ordinateur qui traite le signal et fournit un feedback approprié. La rétroaction des signaux est révélée par moyen d'un jeu à l'écran de l'ordinateur et par de la musique. Quand la personne produit les ondes désirées, le jeu avance et la musique joue. Si elle n'arrive pas à produire les ondes désirées, le jeu et la musique arrêtent. De cette façon, on peut apprendre comment contrôler ses ondes cérébrales pour, par exemple, mieux gérer son attention.

L'ÉLECTROENCÉPHALOGRAMME QUANTITATIF (EEGq)

L'évaluation de l'activité neuroélectrique se fait avec une analyse quantifiée des ondes cérébrales (EEGq). L'emphase principale du neurofeedback n'est pas la qualité des ondes cérébrales (tel qu'analysé par les neurologues pour détecter des crises d'épilepsie ou autres maladies neurologiques), mais plutôt la proportion de certaines ondes cérébrales en relation avec d'autres ondes. L'EEGq est un examen indolore et non invasif. Des électrodes (petits disques de métal) sont posées sur la tête du participant en position assise. Un gel est introduit dans chaque électrode pour assurer un bon contact entre celles-ci et le cuir chevelu. On peut alors étudier l'influence de l'ouverture des yeux par rapport aux yeux fermés sur l'activité cérébrale. Le but du EEGq pour cette étude sera de confirmer la présence d'ondes 'chez les participants et de

s’assurer qu’il n’y a pas déjà un excès d’ondes là ou nous voulons les encourager. Sans la présence de ce schéma, l’entraînement proposé serait une perte de temps pour le participant.

L’ENTRAÎNEMENT EN NEUROFEEDBACK

Avant de commencer chaque séance d’entraînement, des électrodes sont posés à deux endroits sur le cuir chevelu et maintenus en place à l’aide d’une pâte adhésive. Des électrodes sur les lobes d’oreilles servent de références et une électrode posée sur le front sert de mise à la terre. En séance d'entrainement, la personne doit arriver à se concentrer pour diminuer les ondes thêta/alpha ciblées, et augmenter un autre type d’activité cérébrale, soit les ondes SMR. Quand la personne arrive à le faire, un jeu à l’écran de l’ordinateur qui donne la rétroaction avance et la musique joue. Si la personne n’arrive pas à produire les ondes désirées, le jeu et la musique s’arrêtent. De cette façon, le participant peut apprendre à modifier de façon consciente et volontaire l’activité électrique de son cerveau et améliorer son attention. Pendant une séance de neurofeedback le cerveau est entraîné à mieux fonctionner. Après plusieurs séances, le cerveau opte pour ce meilleur fonctionnement.