Supplementary Materials

Brain anatomy alterations associated with Social Networking Site (SNS) addiction

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Appendix A – Neuroscience Glossary

Brain Morphology – Morphology is a term borrowed from biology. It encapsulates a description of the specific structural features of organisms. Applied to the brain, it includes descriptions of the grey matter volumes and content (white matter, CSF, etc.) of specific brain regions, or the whole brain.

Grey Matter – Grey matter includes information processing neuro-components such as neuronal cell bodies, dendrites and axon terminals, as well as fat in the form of glial cells[1,2]. A good analogy for it is a local network of interconnected computing processors which work together on a specific set of tasks. Using this analogy, the neurons process information and communicate via the dendrites attached to them, information to and from other neurons. This structure, since we deal with co-located neurons, resembles this of a local area network, and the processing function of the neurons resembles this of computer processors. The size of this network of neuro-components is captured as grey matter volume (GMV)[3], a measure which we apply in this study.

Amygdala - The amygdala is a pea size structure that exists on each side of the brain (i.e., there is a right and left amygdala). The amygdala is included as a component of the limbic brain system, which is involved in many cue-induced automatic-response processes, such as primary emotions and impulsions[4,5]. For this study, we focus on the amygdala's role in the development of impulsive decisions, which are characteristics of addictive behaviors. In this context, the amygdala is a key component of the neural system that links conditioned cues in the environment to brain neurotransmitter systems concerned with reward, namely mesolimbic dopamine, and its projection to the nucleus accumbens[6]. Engaging this amygdala system through exposure to conditioned environmental cues elicits automatic and obligatory behaviors, or impulsions[7]. This conditioned cues function seems to play a role in producing negative states in response to expectations of, or actual, exposure to drug cues, especially during abstinence, thus promoting problematic behavior reinstatement[8] Hence, besides the nucleus accumbens, the amygdala is also a key substrate involved in the development and maintenance of addictions[9]. Its hyper-sensitization to cues related to the addiction is one brain process that generates strong impulsions and drives the development of addictions[10].

Nucleus Accumbens (NAc) - This region is part of the ventral striatum and is a key element in people's reward system[11]; it is included in the extended amygdala circuitry[8]. Given its centrality in reward anticipation and processing, it is an important component in decision making[12,13]; when it becomes deficient (overly stimulated) it promotes approach behavior which can be risky[7,14]. For instance, in the classic Olds and Milner study, when it was stimulated in rats it promoted continues stimulation seeking at the expense of basic needs such as eating and drinking[15]. As such, the NAc is a key region in addiction formation and maintenance; it mediates reward assessment which promotes the seeking and repetition of behaviors, even when such behaviors are deemed by society to be problematic[7]. As such, it has been implicated in many substance and non-substance addictions, including to alcohol, cocaine, nicotine, cannabis, opiates and gambling[9,16-19].

Anterior-/Mid- Cingulate Cortex (ACC/MCC) - This area is the front to middle part of the cingulate cortex, which surrounds the frontal part of the corpus callosum[20]. The ACC and adjacent MCC are especially relevant for weak inhibition abilities and consequent addictions[21,22]. Its centrality in behavior inhibition processes stems from several tasks with which the ACC/MCC is involved, including monitoring behavioral conflicts[20], reward anticipation and decision making[23,24], processing feedback[25] and impulse control[26]. All of these tasks are important for inhibiting potent and rewarding behaviors, especially when other alternative behaviors are considered and conflict is created (e.g., should I use the SNS now or study for the exam?)[27]. Specifically, the ACC/MCC circuitry is implicated in the assessment of the salience of expected rewards, assessment of motivational content and assigning emotional valence to behavioral choices, resolving decision conflicts and learning to adjust reward assessments through conditional learning[20-23,28]. Moreover, it has extensive connections with the amygdala and it is therefore involved, using the abovementioned mechanisms, in trying to control the impulsions transmitted via the amygdala[21,27]. Note that we focus in this short description only on tasks related to addiction and low inhibition ability. These tasks, however, also make the ACC/MCC an important substrate involved with many other disorders associated with impaired behavioral control abilities, such as attention deficit-hyperactivity, schizophrenia and obsessive-compulsive disorders[21,27]. Taken together, the ACC/MCC has been linked repeatedly and across numerous studies to the ability to self-control or inhibit impulsive behaviors; and as such, deficient ACC/MCC is often involved with addictions[20,21,28-30].

Voxel Based Morphometry (VBM) – VBM is a neuroimaging technique which allows for assessing the grey matter volumes of different brain regions[31]. It is based on images extracted in structural scans and is advantageous compared with traditional morphometry techniques. This advantage lies in the fact that it registers the grey matter encapsulated in each voxel (and its neighbors; through a smoothing process), as opposed to capturing grey matter in full brain regions, and is hence relatively precise in capturing grey matter volumes even is small brain regions (anatomically predefined collections of voxels), such as the amygdala[32]. Each brain is different, and this technique therefore brings all brains to a common space through a three-dimensional stretching process. Comparisons and grey matter extractions for regions of interest are performed in this common space and the results are then de-transformed to the original space[31]. This technique has gained momentum in neuroscience research[33], in part presumably given its advantages compared with and added value to functional imaging techniques[34]. These include task independence (the results will not change if the task changes, like in functional MRI studies), and the natural environment of measurement (variables of interest, such as addiction or task performance are often measured out of the scanner; and only stable structural features are captured in the scanner).

Appendix B – Measures

Table B1: Survey Items

Variable & Source	Items
SNS addiction [35,36]	How often…. (1=Never, 5=Very Often) - do you find it difficult to stop using Facebook when you are online [or bored]? - do you continue to use Facebook despite your intention to stop? - do others (e.g., parents, siblings, friends) say you should use Facebook less? - do you prefer to use Facebook instead of spending time with others (e.g., family, friends)? - are you short of sleep because of Facebook? - do you think about Facebook even when not online? - do you look forward to your next Facebook session? - do you think you should use Facebook less often? - have you unsuccessfully tried to spend less time on Facebook? - do you rush through your homework or chores in order to use Facebook? - do you neglect your daily obligations (school, chores, or family life) because you prefer to use Facebook? - do you use Facebook when you are feeling down? - do you use Facebook to escape from your sorrows or get relief from negative feelings? - do you feel restless, frustrated, or irritated when you cannot use Facebook?
Age	What is your age? ______ years old
Sex	What is your sex? Female (1)/ Male (0)
Contacts	How many contacts do you have on Facebook? ______ contacts
Use frequency	Considering your average behavior for the previous 4 weeks, how many times per day do you use Facebook? ______ times per day
Years of experience	How long ago did you start using Facebook? ______ years
Medical conditions (Exclusion criteria)	Do you have any of the conditions listed below? (Yes/ No/ I do not Know) - non-corrected bad vision - peripheral vascular disease - diabetes - Reynaud's phenomenon – cryoglobulinemia – vasculitis – lupus - any peripheral neuropathies A computerized short version of the structural clinical interview for DSM-IV Disorders (SCID) - Psychoses, Current major depression episode, A history of major depression episodes or major depressive disorder, Heavy drinking, Substance abuse, Pathological gambling, Schizophrenia, Current and history of anxiety disorders, Bipolar disorder

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