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Impact of social media use on executive function

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A R T I C L E I N F O

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A B S T R A C T

Associations between digital dependency and cognition have not received the same attention as emotional and effects, and an area of importance in this regard is Executive Functioning (EF) as there are theoretical debates regrading whether impulse control is a key aspect of functioning for digital dependency. Three experiments examined associations between social media addiction (SMA) and everyday memory (Experiment 1), EF tasks using neutral stimuli before and after social media exposure (Experiments 1 and 2), and deficits in impulse control using social media related and neutral cues (Experiment 3). Experiments1 and 2 demonstrated a relationship between SMA and inhibitory control, as measured by the Iowa Gambling Task (IGT), but less strong associations with attention and attention switching tasks. Experiment 3 demonstrated a relationship between SMA and higher impulsivity using the Go-GoNo task. These relationships were either exacerbated by exposure to social media (Experiment 2), or stronger when performance involved social media related stimuli (Experiment 3). These results are novel as there is very limited evidence relating EF functioning to social media dependency, and they imply a link between SMA and impaired impulse control on exposure to social media related cues.

Digital dependency impacts a range of social and emotional factors, but relatively few studies have examined its impacts on cognitive functioning (Cudo & Zabielska-Mendyk, 2019; Park et al., 2011). Executive Function (EF) is an area thought important to cognitive- and daily-abilities in those who display addictions in general (Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012; Butler & Le Foll, 2019; Cudo & Zabielska-Mendyk, 2019; Domínguez-Salas, Díaz-Batanero, Lozano-Rojas, & Verdejo-García, 2016). However, associations between EF between social media addition (SMA) have not received the same level of attention as for other addictive behaviours (see Cudo & Zabielska-Mendyk, 2019; Park et al., 2011). The current series of experiments aimed to address the gap in the knowledge base, and to explore which aspects of EF are most strongly related to SMA, which has been the subject of some theoretical debate for problematic internet use (PIU) in general.

EF refers to an array of cognitive processes involved in self-regulation, informing future-oriented behaviour, and adaption to the environment, including: working memory, planning, mental flexibility, set-shifting, attention, multitasking, and self-monitoring (Diamond, 2013; Miyake, Emerson, & Friedman, 2000). It is unclear whether one, many, or all, of these abilities are associated with SMA. Some have suggested an association between PIU and impulse control issues (Mazhari, 2012; Park et al., 2011; Reed, Osborne, Romano, & Truzoli, 2015), some have implied an association between PIU and attentional task performance (Fu, Xu, Zhao, & Yu, 2018), and some with EF in general (Mayshak, Sharman, & Zinkiewicz, 2016). However, few (if any) studies have compared the relative impacts of SMA across a range of EF tasks and contrasted this association with the relationships between SMA and other aspects of EF. If a relationship between SMA and impulse control is established that is stronger than that with other aspects of EF, it would add to the suggestion that digital dependency, specifically SMA, may be related to impulse control issues, rather than attention or EF more generally (Cudo & Zabielska-Mendyk, 2019; Tsai, Lu, Hsiao, Hu, & Yen, 2020; Vargas et al., 2019).

A review of the literature relating PIU to EF abilities suggests more evidence for a relationship with impulsivity than with other (perhaps less studied) aspects of EF, and a recent review even suggested PIU is predominantly an inhibition deficit (Cudo & Zabielska-Mendyk, 2019). However, the literature also suggests some contradictory findings that may point to boundaries to this relationship (Akin & Iskender, 2011; Cao, Su, Liu, & Gao, 2007; Zhou, Zhou, & Zhu, 2016a, 2016b), and there is very little known about SMA in this regard. Several behavioural measures of impulsivity involving delayed discounting show a clear relationship with PIU (Mazhari, 2012; Saville, Gisbert, Kopp, & Telesco, 2010), especially just after exposure to the internet (Reed et al., 2015). However, evidence from a task often used to explore EF, the Iowa Gambling Task (IGT), is more mixed; some studies reporting a preference for overall less advantageous but larger rewards by those

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displaying PIU (Xu, 2012), some noting no effect of PIU (Lin, Wang, Sun, Ko, & Chiu, 2019), and some describing a tendency to choose the more overall advantageous options despite them being associated with smaller rewards (Ko et al., 2010).

Association between PIU and inhibitory deficits has been explored using the Go-NoGo task, but this task, similarly, has produced mixed results. In some studies, those displaying PIU perform poorly in terms of inhibiting responses on NoGo trials (Cao et al., 2007; Ding et al., 2014). However, more often there are no differences in behavioural responses for those with PIU, although there are electrophysiological indications of an inhibitory impairment (Dong, Lu, Zhou, & Zhao, 2010; Gao, Jia, Zhao, & Zhang, 2019). Behavioural deficits emerge more clearly on Go-NoGo tasks when the stimuli used are related to internet use, for example gaming-related stimuli (Zhou, Yuan, & Yao, 2012). This suggests exposure to digital cues may be a trigger for such deficits to be shown behaviourally, rather like for impulsivity noted above (Reed et al., 2015).

In addition to impulse control, high levels of inattention also have been noted to correlate with PIU in some studies (Seyrek, Cop, Sinir, Ugurlu, & Şenel, 2017; Yen, Yen, Chen, Tang, & Ko, 2009), and orienting attention to detect targets shows an increase in reaction time for those with PIU (Fu et al., 2018). In terms of the Stroop effect, often used to assess attentional ability, reaction to words in the presence of a distractor has been found to be longer by those with PIU (Kuo et al., 2018), especially when the words are computer-related words (Jeromin, Nyenhuis, & Barke, 2016). Emotional Stroop deficits have also been noted for those with PIU (Dieter et al., 2017). Likewise, attention switching is an important construct of EF (Hanania & Smith, 2010), and impairments in shifting attention have been noted for many addictions (Kübler, Murphy, & Garavan, 2005; Odlaug, Chamberlain, Kim, Schreiber, & Grant, 2011). There are more perseverative errors made on a Wisconsin Card Sort Task (WCST) for those with PIU (WCST; Kuo et al., 2018; Zhou et al., 2016a, 2016b). However, there is little evidence relating performance on any of these tasks to SMA, rather than to PIU in general.

Exploring the relative strength of these associations with SMA this is a key aim of the current series of experiments, as they may help to address the issue of whether SMA is primarily associated with impulse control issues (Cudo & Zabielska-Mendyk, 2019). Moreover, the literature relating to PIU suggests that any such deficits may not be generalised across all aspects of an individual's functioning, but they may be revealed when they are exposed to contexts or cues relating to the internet. The current studies also examined whether the relationships between SMA and aspects of EF were similarly context dependent. This may have implications for the targeting of any treatment for such a process addiction. Beyond these associations, of clinical relevance to addictions are impairments in everyday memory (Bouazzaoui et al., 2010; Hammersley, 1994), which have been extensively demonstrated in substance abuse (e.g., Weinborn, Woods, O'Toole, Kellogg, & Moyle, 2011). In terms of PIU and social media problems, a smaller number of studies have shown a link between impairment in everyday cognitive functioning (Hadlington, 2015; Sharifian & Zahodne, 2020), but further data would be of benefit. This association between SMA and everyday memory also is a target of the current studies.

The above summary has suggested associations between PIU and deficits on several EF tasks, such as the IGT, Stroop, and WCST, but that the strongest evidence is for a relationship with impulse control. The research also suggests that these deficits may be larger when performance is related to digitally-associated cues or internet exposure. However, there is limited evidence relating EF functioning to SMA. Given this, a series of experiments explored EF in relation to SMA, and examined the effect of exposure to social media related cues. Based on the PIU literature, it is suggested that there will be associations between SMA and everyday memory problems, and with impulse control tasks – those reporting SMA problems having more memory problems and worse impulse control. It is also suggested that the relationship between SMA and impulse control issues will be especially pronounced when participants are exposed to social media cues or contexts. The expected relationship between SMA and other aspects of EF, such as attention switching, is less clear; but these associations are less pronounced than with impulse control it will give strength to the suggestion the SMA, is in large degree, a problem of impulsivity.

1. Experiment 1

The first study measured the relationship between SMA, everyday memory, and EF abilities. It explored the relationship between everyday memory problems and SMA, which has been found to be impaired (Hadlington, 2015; Sharifian & Zahodne, 2020). The current study used two widely-used self-report scales for everyday memory problems that have previously been employed in substance use research (Weinborn et al., 2011); the 'everyday memory questionnaire', and the 'prospective and retrospective memory questionnaire'. In addition, a battery of EF tasks was explored: attention-shifting (WCST), attention (Stroop), and impulsivity (IGT) to examine whether there were any differentially relationships between SMA and aspects of EF. The current task used standard versions of these tasks employing neutral (non-digitally related) stimuli to clarify any effects of SMA on such tasks (cf. Ding et al., 2014; Dong et al., 2010; Lin et al., 2019).

2. Method

2.1. Participants

Participants were recruited via social media platforms. The study recruited 456 participants, 78 (17%) failed to complete the study, leaving a total of 378 participants (228 female; 144 male; 6 nonbinary), with a mean age of 28.56 (±12.72; range = 18–63). G-Power calculations for a medium effect size ($f^2(V) = 0.063$), 80% power, and a $p < .05$ criteria, suggested that 180 participants would be needed for a MANOVA with 3 dependent variables and two groups (lower and higher social media addiction). Participants gave informed consent prior to beginning the study, which was given ethical approval by the University's Department of Psychology Ethics Committee.

2.2. Materials

Bergen Social Media Addiction Scale (SMAS; Andreassen et al., 2012) is a 6-item self-report scale examining social media addiction. Each question is answered on a 5-point Likert scale (1 = 'not at all'; 5 = 'very frequently'). Scores range from 6 to 30, with higher scores reflecting greater social media dependency problems, and a score of 24 taken as cut-off for problematic usage. The internal reliability of the questionnaire for the current sample, as determined by Cronbach α, was 0.845.

Everyday Memory Questionnaire (EMQ-R; Royle & Lincoln, 2008) is a 20-item self-report scale of everyday memory, with each item reflecting an everyday activity that may involve forgetting (e.g., '*telling somebody a joke or story you have told them before*'; '*forgotten to tell somebody something important*'). Questions are answered on a Likert scale, ranging from 1 to 9. The minimum score is 20, and the maximum is 180. Higher scores reflect more problems with memory. The internal reliability for the current sample (Cronbach α) was 0.922.

Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000) is a 16-item self-report measure of prospective (8-items; e.g., '*deciding to do something in a few minutes' time and then forgetting to do it*'; '*forgetting appointments if you are not prompted by someone else*') and retrospective (8-items; '*forgetting something that you were told a few minutes before*'; '*looking at something without realising you have seen it moments before*') memory failures. Each question is answered on a 5-point Likert scale. The minimum score for the overall questionnaire was 16 and the maximum being 80, with higher scores indicating more failures of memory. The Internal reliability for the current sample (Cronbach α) was 0.860.

Wisconsin Card Sorting Task (WCST; Grant and Berg, 1948) is an experimental paradigm used to assess attention switching ability. The participant is shown four cards, of which have different properties in colour (red, blue, green, yellow), shape (triangles, circles, crosses and stars), and number of items on one card. Another card, independent from the four, is displayed below the decks, and participants are required to sort this card into one of the four decks based upon a rule. The participant is unaware of the rule, but are given feedback after every response, notifying them whether their response is correct or not. Throughout the task, the rule can change without notifying the participant. There were 128 trials in total, taking approximately 10 min to complete. The current analysis focused on perseverative errors (the number of errors made after a rule was switched), with higher scores meaning more interference.

Colour-Stroop Task (Stroop, 1935) is an experimental paradigm designed to assess attention and inhibition ability. The aim of the task is to correctly respond to the colour of ink a word is when displayed on the screen. The selection of colour was established by a corresponding number on the keyboard. To help the participant, this information was displayed on every trial to remind them of the correct key for each response. The word displayed may have been congruent with the colour (e.g., the word 'yellow' in the colour yellow), or incongruent with the corresponding colour (e.g., the word 'yellow' in the colour red). There were trials which displayed neutral words such as 'and' and 'over'. When a participant failed to correctly respond to the correct colour ink, it demonstrates an inability to show attentional inhibition. In each trial, participants were given 2s to respond. If they failed to do this the words 'too slow' were displayed. Participants are provided with a practice round to enable time to get used to the process. A comparison between reaction times for neutral and incongruent trials was calculated – with higher scores representing more interference. This task took approximately 6 min.

Iowa Gambling Task (IGT; Bechara, Damasio, Tranel, & Damasio, 2005) is an experimental paradigm designed to assess impulsivity in relation to a gambling scenario. The task begins by presenting the participant with £2000, and four decks of cards (labelled A, B, C or D). The aim is to gain as much hypothetical money as possible by clicking on any one of the four decks. Participants receive instant feedback informing them of their winnings or losses. Participants are not informed about which decks are good or bad and must work out their method of choice through experimenting themselves. Decks A and B offer rewards of £100, whereas Decks C and D offer rewards of £50. For each deck, there is 50% chance of getting a penalty. Larger penalties were given to participants for selecting A and B. There are 100 trials, taking each participant approximately 10–15 min to complete. Impulsivity was measured by subtracting percentage choses for deck C and D from choices from decks A and B (higher immediate reward but overall losses). Participants could achieve a score of between −100 and + 100, with the higher scores resulting in more impulsive responses.

2.3. Procedure

Participants were linked to the study portal via a direct URL link, with a brief overview of the study explained alongside. When the link to the study portal was clicked, participants were directed to the Gorilla platform, where the study could be conducted. Participants clicked 'begin' which was followed by an information sheet outlining the study details, including how their data would be used, what to expect in the study and providing a disclosure for some potentially sensitive content. Once the information sheet had been reviewed, participants then clicked next to reach a consent form.

Participants were then asked to fill out a questionnaire relating to general demographics, including details on age, gender, occupation and ethnicity. Once complete, participants completed the experimental tasks (randomised across participants), and then the questionnaires, randomised across participants, with the exception that the BSMAS was always presented last. There were breaks given to each participant between each task, which in together took approximately 30 min.

When the questionnaires had been completed, participants were directed to a debrief form. This outlined the aims and hypothesis of the study, while also informing the participant of any relevant links for more information and contact details of the researchers. Participants then clicked 'finish', which closed the window or directed them back to participant pool where credits were granted if this was how they accessed the study.

3. Results and discussion

The mean SMA score for the sample was 13.21 (±6.25; range = 6–30). Of the sample, 37 (10%) scored above cut-off for social media dependency (i.e. 24). The mean for females was 14.21 (±6.83; range = 6–30) and for males 11.54 (±4.78; range = 6–30). An independent samples *t*-test (along with effect size, 95% confidence limits, and the appropriate Bayes statistic) revealed a significant difference between the groups, $t(370) = 4.08$, $p < .001$, $d = 0.434$ [*95%CI* = 0.223:.645], $p(H_1/D) = 0.996$ (no analyses were conducted using nonbinary due to very low numbers). There were 35/228 (15%) females and 1/144 (1%) males scoring above cut-off for social media dependency, $X^2(1) = 21.69$, $p < .001$, $\varphi = 0.241$.

Fig. 1 shows the Pearson correlations between SMA (BSMAS), prospective and retrospective memory problems (PRMQ), and everyday memory problems (EMQ), along with the scatterplots, 95% confidence limits, and density plots for each variable. Inspection of these data shows statistically significant ($p < .001$), moderate size correlations between SMA and both sorts of memory problems. As the data from the scales was somewhat positively skewed, Spearman's correlations were also conducted, which revealed a similar pattern of associations: SMA and PRRQ = .243, $p < .001$; SMA and EMQ = 0.407, $p < .001$; PMRQ and EMQ = 0.349, $p < .001$. Those with higher SMA had poorer everyday memory, and prospective and retrospective memory, both of these functions have been associated with EF previously (Bouazzaoui et al., 2010; Hammersley, 1994). Moreover, these memory functions have previously been noted to be impaired in those with SMA (Hadlington, 2015; Sharifian & Zahodne, 2020).

Fig. 2 shows the Pearson correlations between SMA (BSMAS), and each of the standardised scores for the EF tasks (WCST, Stroop, and IGT), along with the scatterplots, 95% confidence limits, and density plots for each variable. Inspection of these data shows no relationship between SMA and either WCST perseverative errors, or Stroop reaction time. There was a small positive relationship with IGT impulsive choices. This pattern of association was present when Spearman correlations were conducted; relationship between SMA and: WCST = −.031, $p > .50$; Stroop = −0.077, $p = .136$; IGT = 0.196, $p < .001$. Such small associations with the WCST and Stroop have previously been reported, when using tasks of neutral stimuli, and the effect relating to IGT has previously been seen in some studies (Xu, 2012).

The sample was split at the cut-off for SMA (BSMAS = 24) to create a no SMA group ($N = 341$; BSMAS = 11.69 ± 4.41; range = 6–23), and an SMA group ($N = 37$; BSMAS = 27.16 ± 2.03; range = 24–30). The three measures of EF were turned into Z-scores to allow presentation on the same scale, and the means for these tasks for the no SMA and SMA groups are shown in Fig. 3. A multivariate analysis of variance (MANOVA) conducted on these data revealed a significant difference between the groups, *Pillai's Trace* = 0.032, $F(3,374) = 4.18$, $p = .006$, $\eta_p^2 = .032$ [0.003:.069], $p(H_1/D) = 0.637$. Univariate analyses of variance (ANOVA) conducted on each variable separately (using a Bonferroni correction = 0.05/3 = 0.016) revealed no difference between the groups for WCST errors, $F(1,376) = 2.24$, $p = .121$, $\eta_p^2 = .013$[0.000:.031], $p(H_0/D) = 0.857$, or Stroop reaction time, $F(1,376) = 1.85$, $p = .175$, $\eta_p^2 = .006$[0.000:.028], $p(H_0/D) = 0.889$, but the SMA group was more

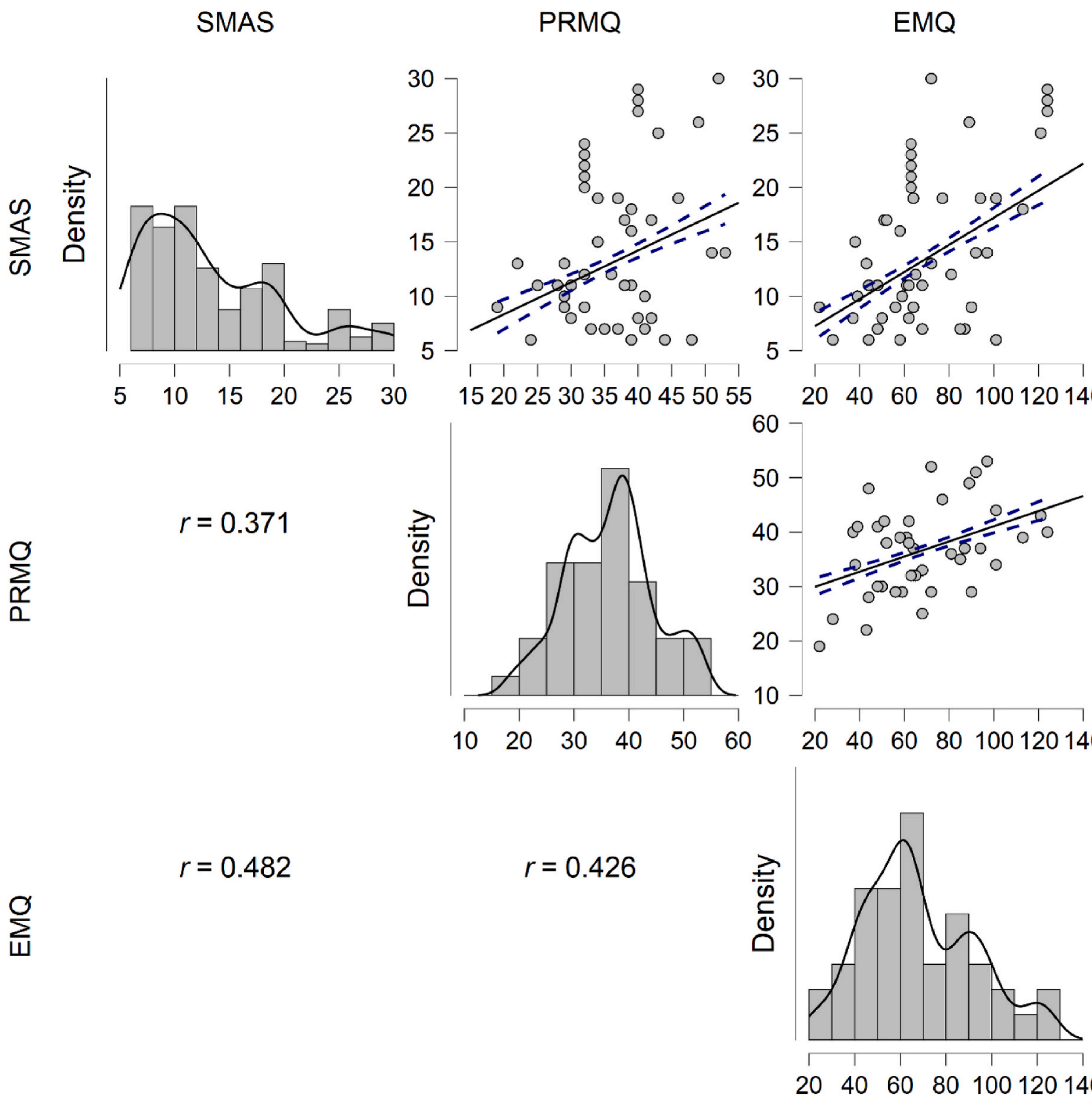

Fig. 1. Experiment 1. Pearson correlations between social media dependency (SMAS), prospective/retrospective memory problems (PRMQ), and everyday memory problems (EMQ), along with the scatterplots and 95% confidence limits, and density plots for each variable.

impulsive on the IGT task, $F(1,376) = 7.71$, $p = .006$, $\eta_p^2 = .020$ [0.002:.056], $p(H_1/D) = 0.663$.

A discriminant function analysis conducted to differentiate between no SMA and SMA groups found the first function significant, *Wilks Lambda* = 0.968, $X^2(3) = 12.36$, $p = .006$, $\varphi = 0.339$. According to the structure matrix, the first function involved IGT impulsivity (0.782), but there were less strong loadings for WCST perseverative errors (0.438), and Stroop reaction time (−0.383). The function predicted the presence of AD with 66% accuracy.

The current results suggest the strongest relationship between SMA and EF abilities is with impulse control (IGT), rather than with attentional tasks (WCST or Stroop). This is consistent with reports of the relationship between PIU and impulse control (Mazhari, 2012; Reed et al., 2015; Saville et al., 2010), and supports suggestions that digital dependency is predominantly an impulse control problem (see Cudo & Zabielska-Mendyk, 2019). It might be noted that several studies have noted a relationship between PIU and attention, when measured by the WCST using neutral stimuli (Kuo et al., 2018; Zhou et al., 2016a, 2016b). However, no strong effect was noted for SMA with the WCST in the current study. This may imply a difference between PIU and SMA. It should be noted also that the lack of a strong relationship between PIU and attention as measured by the Stroop effect may be connected with the use of neutral words, as previous demonstrations of a relationship with PIU have found such an effect when using computing-related words (Jeromin et al., 2016).

4. Experiment 2

The second experiment extended the Experiment 1 in two ways. Firstly, it sought to confirm the findings relating to EF and SMA reported in Experiment 1, given that there has been mixed pattern of data reported in the literature with respect to PIU, and very little data relating to SMA. Secondly, it examined whether exposure to social media would have an impact subsequently on EF functioning. In several studies it has been shown that EF deficits, especially inhibitory problems, emerge more strongly after exposure to the internet or digitally-related stimuli (Jeromin et al., 2016; Reed et al., 2015). To this end, the second experiment addressed the effect of social media exposure on EF. The battery of EF tests described in Experiment 1 were given once before social media exposure, and then again after social media exposure, to

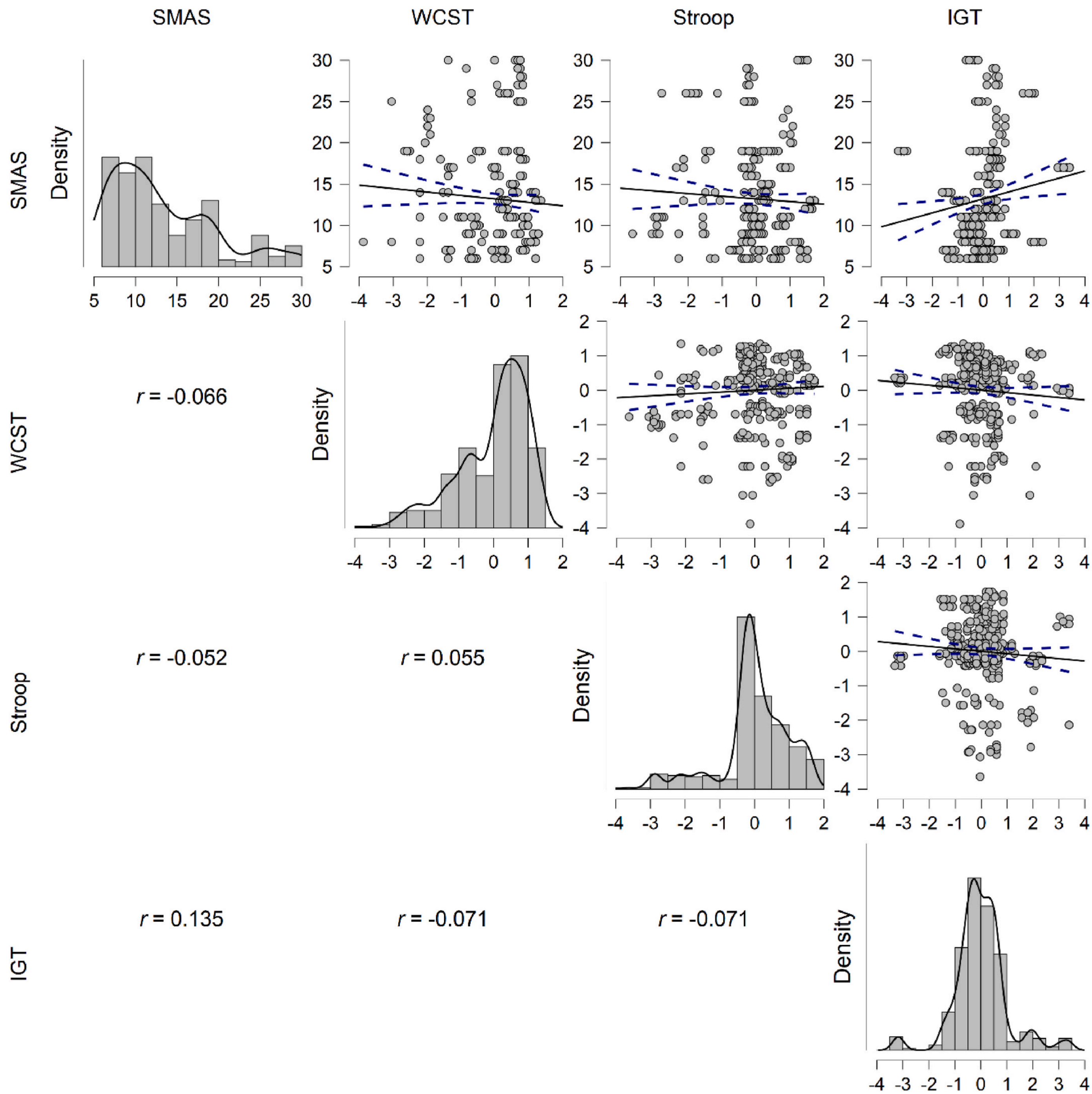

Fig. 2. Experiment 1. Pearson correlations between social media dependency (SMAS), and each of the standardised EF task scores (WCST perseverative errors, Stroop reaction time, and IGT impulsive choices), along with the scatterplots and 95% confidence limits, and density plots for each variable.

assess any change in performance. Based on the results from Experiment 1 it might be predicted that on the first exposure IGT impulsivity would be higher for those with SMA, and that this would get worse after exposure.

5. Method

5.1. Participants and materials

Participants were recruited via advertisement on the Psychology subject pool. The study recruited 167 participants, 7 (5%) failed to complete the study, leaving a total of 160 participants (114 female; 46 male), with a mean age of 21.05 (±1.76; range = 18–28). G-Power calculations for a medium effect size ($f(V)$ = 0.25), 80% power, and a $p < .05$ criteria, suggested that 158 participants would be needed to detect an interaction for a mixed model MANOVA with 3 dependent variables and two groups. Participants gave informed consent prior to beginning the study, which was given ethical approval by the University's Department of Psychology Ethics Committee.

The Bergen Social Media Addiction Scale (SMAS; Andreassen et al., 2016), Iowa Gambling Task (IGT; Bechara et al., 2005), Wisconsin Card Sorting Task (WCST; Grant & Berg, 1948), and Colour-Stroop Task (Stroop, 1935), were employed as described in Experiment 1.

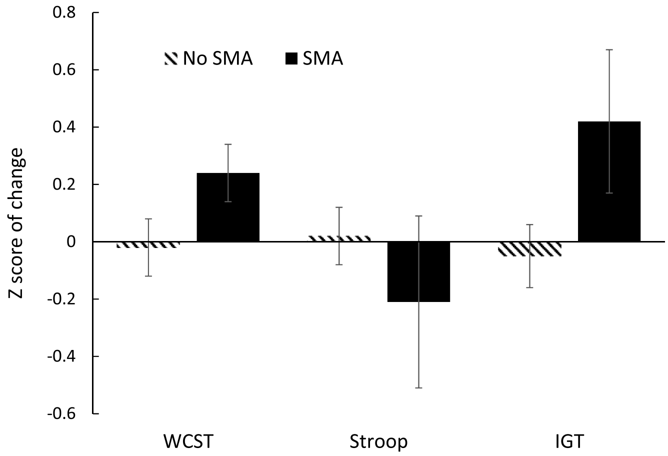

Fig. 3. Experiment 1. Mean Z scores for EF tasks (WCST = perseverative errors; Stroop = reaction time; IGT = Iowa Gambling Task impulsive choices) for no social media dependency group and the social media dependency group. . Error bars = 95% confidence limits.

5.2. Procedure

Participants were tested in individual cubicles containing a desk, computer, and a chair. They were presented with an information sheet giving an overview of the study. The right to withdraw was stated clearly. When they had read the information sheet, and were happy to proceed, they signed a consent form. The participant then completed the three EF experimental tasks as described in Experiment 1, with the exception that these were not presented online. The tasks were completed in a random order by every participant. Upon completion of these experiments, participants were randomly allocated, to either be exposed to their smartphones for social media use, or were given a distractor task involving reading a passage of a novel of their choice, for approximately 10 min. Participants were not disturbed during this time, and they were free use their mobiles for social media purposes in any way that they wished. After the 10 min period they interrupted by a researcher, and asked to complete all three experimental tasks again. Upon completion of the experimental tasks the second time (in a randomised order across (participants), the BSMAS was completed. Participants were then given a debrief form, asked if they had any questions, and thanked for their participation.

6. Results and discussion

The mean SMA score for the sample was 18.44 (±5.81; range = 6–30). Of the sample, 40 (25%) scored above cut-off for social media dependency (i.e 0.24). The mean for females was 18.72 (±5.93; range = 6–30) and for males 17.73 (±5.60; range = 8–27), $t(158) = 0.97$, $p > .30$, $d = 0.169[-0.174{:}.512]$, $p(H_0/D) = 0.714$. There were 30/114 (26%) females and 10/46 (21%) males scoring above cut-off for social media dependency, $X^2(1) = 0.152$, $p > .60$, $\varphi = 0.031$.

Fig. 4 shows the Pearson correlations between SMA (SMAS), and each of the standardised scores for the EF tasks (WCST, Stroop, and IGT) at time 1, along with the scatterplots, 95% confidence limits, and density plots for each variable. Inspection of these data shows no relationship between social media dependency and either WCST perseverative errors, or Stroop reaction, but there was a small positive relationship with impulsive choices on the IGT. In order to accommodate any deviation from normality in distribution, this pattern of association was explored using Spearman correlations, and the relationships were between SMA and: WCST = .073, $p > .30$; Stroop = .120, $p = .131$; IGT = −0.346, $p < .001$. These pattern of significance in these data was similar to that reported in Experiment 1, again suggesting the SMA is primarily, although not exclusively, an inhibition problem (Cudo & Zabielska-Mendyk, 2019).

The sample was split at the cut-off for SMA (BSMAS = 24), to create a no SMA group ($N = 120$; BSMAS = 15.84 ± 4.13; range = 6–23), and an SMA group ($N = 40$; BSMAS = 26.25 ± 1.90; range = 24–30). The three measures of EF at time 1 were turned into Z-scores to allow presentation on the same scale, and the means for these tasks for the two groups at time 1 are shown in Fig. 5. A MANOVA conducted on these data revealed a significant difference between the groups, *Pillai's Trace* = 0.076, $F(3,156) = 4.28$, $p = .006$, $\eta_p^2 = .081[0.007{:}.160]$, $p(H_1/D) = 0.611$. Univariate analyses ANOVAs (using a Bonferroni correction = 0.05/3 = 0.016) conducted on each variable revealed no difference between the groups for WCST errors, $F(1,158) = 4.15$, $p = .043$, $\eta_p^2 = .028[0.000{:}.091]$, $p(H_0/D) = 0.619$, or Stroop reaction time, $F(1,158) = 1.08$, $p > .30$, $\eta_p^2 = .007[0.000{:}.053]$, $p(H_0/D) = 0.884$, but the SMA group was more impulsive on the IGT task, $F(1,158) = 6.32$, $p = .013$, $\eta_p^2 = .038[0.002{:}.111]$, $p(H_1/D) = 0.636$.

A discriminant function analysis conducted to differentiate between no SMA and SMA groups found the first function significant, *Wilks Lambda* = 0.924, $X^2(3) = 12.39$, $p = .006$, $\varphi = 0.278$. According to the structure matrix, the first function involved IGT impulsivity (0.696) and WCST perseverative errors (0.565), but there was a less strong relationship with Stroop reaction time (−0.288). The function predicted the presence of AD with 63% accuracy.

To analyse the effect of social media exposure, the sample was divided at the cut-off for SMA (BSMAS = 24) to create four groups: a non-exposed no SMA group ($N = 61$; BSMAS = 15.72 ± 3.52; range = 8–20), a non-exposed SMA group ($N = 20$; BSMAS = 26.50 ± 1.23; range = 25–29), an exposed no SMA group ($N = 59$; BSMAS = 15.99 ± 4.71; range = 6–23), and an exposed SMA group ($N = 20$; BSMAS = 26.00 ± 2.41; range = 24–30). The change in the EF task between time 1 and time 2 (time 2 minus time 1) was calculated, and these change scores for each EF task were standardised to allow presentation on the same scale. The means for the change scores for the three EF tasks are shown in Fig. 6. A two-factor MANOVA (exposure x social media dependency) revealed a significant main effect of exposure, *Pillai's Trace* = 0.273, $F(3,154) = 19.27$, $p < .001$, $\eta_p^2 = .273[0.151{:}.369]$, $p(H_1/D) = 0.876$, no significant main effect of SMA, *Pillai's Trace* = 0.001, $F(3,154) = 0.011$, $p > .90$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$, but a significant interaction, *Pillai's Trace* = 0.048, $F(3,154) = 2.62$, $p = .050$, $\eta_p^2 = .048[0.000{:}.114]$, $p(H_1/D) = 0.597$. A two-factor ANOVA (exposure x social media dependency) conducted on the WCST data revealed no significant main effects of exposure, $F < 1$, $\eta_p^2 = .001[0.000.001]$, $p(H_0/D) = 0.999$, or SMA, $F < 1$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$, and no interaction, $F < 1$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$. A two-factor ANOVA (exposure x social media dependency) conducted on the Stroop data revealed no significant main effects of exposure, $F < 1$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$, or social media, $F < 1$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$, and no interaction, $F < 1$, $p > .30$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$. However, a two-factor ANOVA (exposure x social media dependency) conducted on the IGT data revealed a significant main effect of exposure, $F(1,156) = 50.68$, $p < .001$, $\eta_p^2 = .245[0.137{:}.350]$, $p(H_1/D) = 0.999$, no significant main effect of social media, $F < 1$, $\eta_p^2 = .001[0.000{:}.001]$, $p(H_0/D) = 0.999$, but a significant interaction, $F(1,156) = 7.44$, $p = .007$, $\eta_p^2 = .046[0.025{:}.121]$, $p(H_1/D) = 0.737$. Simple effects analysis revealed that the change in impulsivity was not different between the SMA groups when not social media exposed, $F(1,156) = 2.92$, $p = .010$, $\eta_p^2 = .018[0.000{:}.089]$, $p(H_0/D) = 0.737$, but it was after social media exposure, $F(1,156) = 3.12$, $p = .050$, $\eta_p^2 = .020[0.000{:}.081]$, $p(H_1/D) = 0.655$.

These data are consistent with a number of previous reports that exposure to computer-related cues makes EF performance worse in those with digital dependency problems (see Reed et al., 2015; Zhou et al., 2012), but is the first to demonstrated this in regard to SMA and actual exposure to social media (as opposed to computer-related cues). That the effect is largely related to poor IGT performance is consistent with previous suggestions that such a problem is related to impulsivity (Cudo

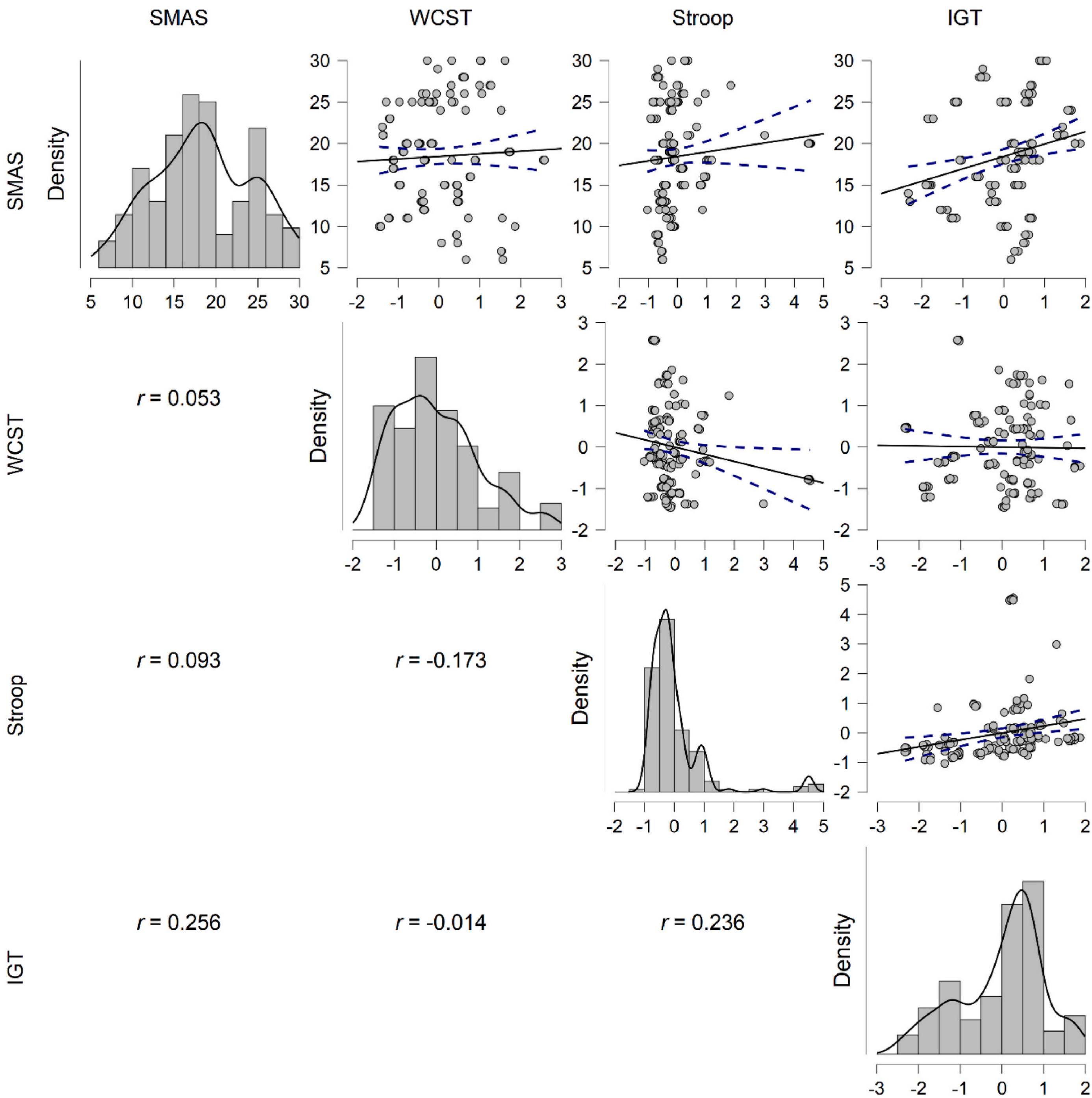

Fig. 4. Experiment 2. Pearson correlations between social media dependency (SMAS), and each of the standardised EF task scores (WCST perseverative errors, Stroop reaction time, and IGT impulsive choices), along with the scatterplots and 95% confidence limits, and density plots for each variable.

& Zabielska-Mendyk, 2019).

7. Experiment 3

The final experiment in this series explored the relationship between SMA and inhibitory control using the Go-NoGo task, which is typically taken to measure impulsiveness. As noted above, studies examining the relationship between PIU and inhibitory control using neutral stimuli have often noted no differences in behavioural responses (Dong et al., 2010; Gao et al., 2019). In contrast, behavioural deficits in terms of impulsivity emerge more clearly on Go-NoGo tasks when the stimuli used are related to internet use, for example gaming-related stimuli (Zhou et al., 2012). This suggests exposure to digital cues may be a trigger for such behavioural deficits to be shown behaviourally (see current Experiment 2; Reed et al., 2015). However, again, there is little evidence in relation to SMA. Given this, the current study employed a design like that described in Experiment 1, but measured impulsivity with a Go-NoGo task that used either social media related stimuli, or stimuli neutral with respect to social media. Based on previous results, it might be expected that there would be an association between SMA and impulsivity on the Go-NoGo task when the cues were social media related, but not when they were neutral.

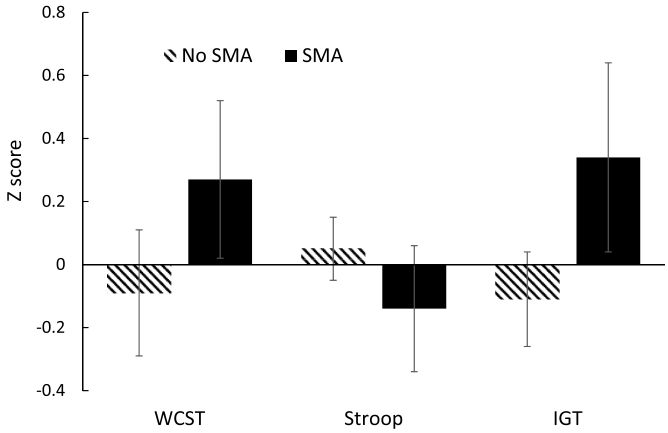

Fig. 5. Experiment 2. Mean Z scores for EF tasks (WCST = perseverative errors; Stroop = reaction time; IGT = Iowa Gambling Task impulsive choices) for no social media dependency group and the social media dependency group. . Error bars = 95% confidence limits.

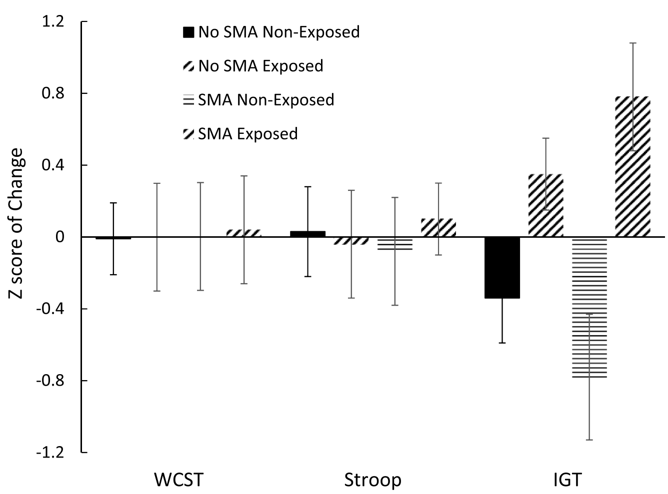

Fig. 6. Experiment 2. Mean Z scores for changes in the executive functioning tasks (time 2 minus time 1) for the no social media dependency group and the social media dependency group. WCST = perseverative errors; Stroop = reaction time; IGT = Iowa Gambling Task impulsive choices. Error bars = 95% confidence limits.

8. Method

8.1. Participants

Participants were recruited via social media platforms. The study recruited 432 participants, 85 (19%) failed to complete the study, leaving a total of 347 participants (192 female; 135 male; 20 nonbinary), with a mean age of 25.13 (±3.81; range = 18–36). G-Power calculations for a medium effect size ($f^2(V) = 0.063$), 80% power, and a $p < .05$ criteria, suggested that 126 participants would be needed. Participants gave informed consent prior to beginning the study, which was given ethical approval by the University's Department of Psychology Ethics Committee.

8.2. Materials

Bergen Social Media Addiction Scale (SMAS; Andreassen et al., 2012) as decribed in Experiment 1.

Go-NoGo Test measures impulsivity by presenting two sets of stimuli: the social media condition presented logos related to social media (Facebook, Instagram, Snapchat and TikTok), which acted as the Go component in the test, and disarranged social media logos were the NoGo component; the neutral stimuli were non-social media logos (McDonalds, Starbucks, Mercedes-Benz and Coca-Cola), with the clear logo being the Go component, and the disarranged logo being the NoGo component. During the task a fixation point was provided in the middle of the screen between each presentation. The stimuli were presented on a white background.

8.3. Procedure

Participants clicked a link to the experiment after reading an information sheet, consented to the experiment, and were presented with further instructions, and then with the experimental task. The social media and neutral conditions were presented in random order across participants. Each condition comprised 300 trials, of which 200 were Go, and 100 were NoGo. In between each trial, stimuli a fixation point was presented on screen for 200 ms. Each stimulus was presented on screen for 1500 ms. Once the participant had pressed the spacebar, the stimulus would be taken off screen, and the fixation point would be displayed. The Go-NoGo test took approximately 20 min. Once the Go-NoGo test was completed by the participants, they proceeded to answer the questions to the SMAS. Once the questionnaires were all filled out the participants were presented with a debrief form.

9. Results and discussion

The mean SMA score for the sample was 14.72 (±6.83; range = 6–30). Of the sample, 57 (16%) scored above cut-off for social media dependency (i.e. 24). The mean for females was 15.28 (±6.90; range = 6–30) and for males 13.98 (±7.13; range = 6–29), $t(325) = 1.70$, $p = .099$, $d = 0.191[-0.029:.412]$, $p(H_0/D) = 0.721$. There were 36/192 (19%) females and 18/135 (13%) males scoring above cut-off for social media dependency, $X^2(1) = 1.687$, $p = .194$, $\varphi = 0.072$.

Fig. 7 shows the Pearson correlations between SMA (SMAS), and the errors made on the NoGo trials for both conditions (social media stimuli and neutral stimuli). Inspection of these data shows statistically significant small size positive correlation between SMA and errors made on social media related condition, but not for the neutral condition. To accommodate any deviation from normality in distribution, this pattern of association was explored using Spearman correlations, and the relationships were between SMA and: SM errors = 0.369, $p < .001$; Neutral errors = 0.101, $p = .061$.

The sample was split at the cut-off for SMA (SMAS = 24), to create a no SMA group ($N = 290$; SMAS = 12.37 ± 4.69; range = 6–22), and an SMA group ($N = 57$; SMAS = 26.63 ± 1.58; range = 24–30). Fig. 8 displays the group-mean errors (impulsivity) made on NoGo trails in the two conditions (social media stimuli and neutral stimuli). Inspection of these data shows that in the social media condition, the SMA group were more impulsive (made more errors) than the no SMA group. However, this pattern of data was not seen for the neutral Go-Nogo task, where there was little difference between the groups. A mixed-model ANOVA (social media dependency x condition) revealed a significant main effect of condition, $F(1,345) = 6.32$, $p = .012$, $\eta_p^2 = .018[0.001:.055]$, $p(H_1/D) = 0.554$, no main effect of group, $F(1,345) = 1.82$, $p = .178$, $\eta_p^2 = .005$ $[0.000:.031]$, $p(H_0/D) = 0.883$, but a significant interaction, $F(1,345) = 9.80$, $p = .002$, $\eta_p^2 = .028[0.004:.070]$, $p(H_1/D) = 0.874$. Simple effect analyses revealed a significantly higher number of errors for the SMA group in the social media condition, $F(1,345) = 22.50$, $p < .001$, $\eta_p^2 = .061[0.021:.116]$, $p(H_1/D) = 0.999$, but no difference between the groups in the neutral condition, $F(1,345) = 2.14$, $p < .144$, $\eta_p^2 = .006$ $[0.000:.033]$, $p(H_0/D) = 0.863$.

These results suggest an association between SMA and impulsivity on the Go-NoGo task when the cues were social media related, but not when they were neutral. This corroborates results reported in several previous studies (Dong et al., 2010; Gao et al., 2019; Zhou et al., 2012). These

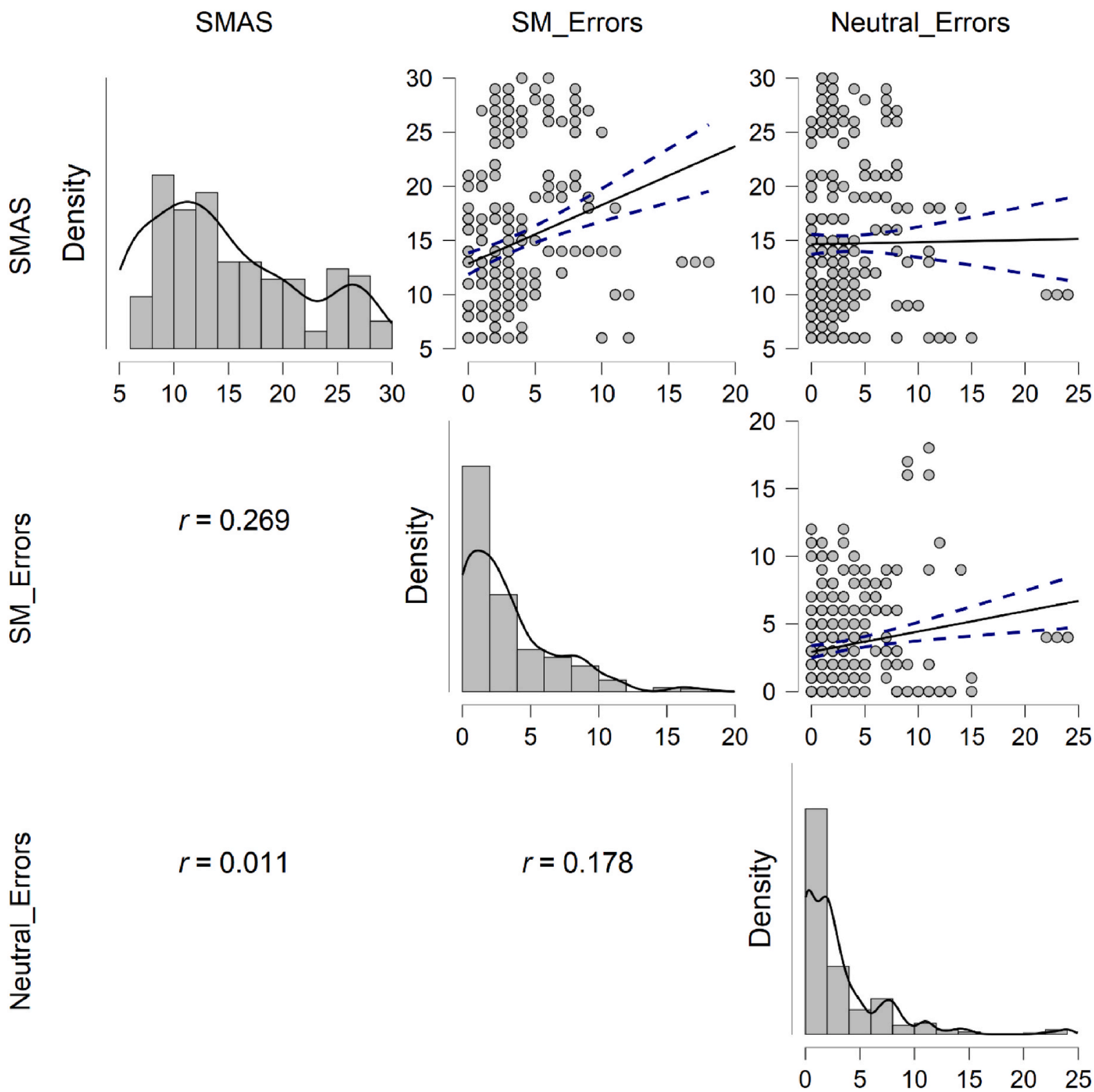

Fig. 7. Experiment 3. Pearson correlations between social media dependency (SMAS), and errors made on NoGo trials in both the social media stimuli and neutral stimuli conditions, along with the scatterplots and 95% confidence limits, and density plots for each variable.

results are also consistent with the findings from the current Experiment 2 regarding inhibitory control (see also Reed et al., 2015). The pattern of findings suggests that, while those with higher social media addiction show a tendency to be more impulsive in the presence of cues related to social media, this is not necessarily a general tendency that is seen in other areas of their functioning. That is, the impulsivity deficit is related to cues associated with their addiction.

10. General discussion

The current series of experiments examined associations between SMA and a range of cognitive functions, including everyday memory (Experiment 1), EF involving attention, attention switching, and impulsivity, using neutral stimuli before and after social media exposure (Experiments 1 and 2), and deficits in impulsivity using social media related and neutral cues (Experiment 3). A core question was whether the relationship between SMA and impulse control was stronger than that with other aspects of EF, as this would add to the suggestion that SMA may be related to impulse control issues rather than EF more generally (Cudo & Zabielska-Mendyk, 2019; Tsai et al., 2020; Vargas et al., 2019).

Experiments1 and 2 demonstrated a relationship between SMA and reward sensitivity and impulsivity as measured by the IGT, but less strong associations with attention and attention switching tasks, and Experiment 3 demonstrated a relationship between SMA and impulse control problems on the Go-GoNo task. These relationships were either exacerbated by exposure to social media (Experiment 2), or stronger when performance involved social media related stimuli (Experiment 3). These results are novel in the sense that there is limited evidence relating EF functioning to social media dependency, as opposed to PIU. The associations between digital dependency and cognitions have not received the same level of attention as psychosocial effects (Cudo & Zabielska-Mendyk, 2019; Park et al., 2011), and an area of importance in this regard is EF (Bickel et al., 2012; Cudo & Zabielska-Mendyk, 2019; Domínguez-Salas et al., 2016).

The pattern of data suggests an association between SMA and impulse control issues, rather than with attentional performance or executive function more generally (see Cudo & Zabielska-Mendyk, 2019). That there was no impact of exposure to social media on either Stroop or WCST tasks, as there was on IGT performance, suggests that

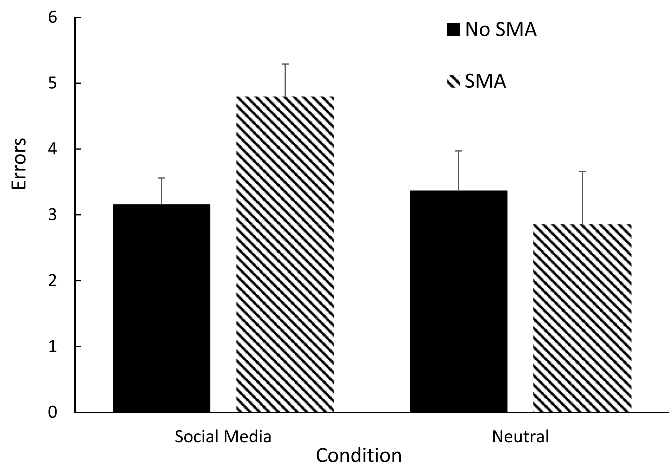

Fig. 8. Experiment 3. Mean Z scores for NoGo errors in the social media and neutral stimuli conditions for the no social media dependency group and the social media dependency groups. Error bars = 95% confidence limits.

impulse-related tasks are most strongly related to SMA as has been implied in reviews of the literature (Cudo & Zabielska-Mendyk, 2019). Such a finding has been reported for PIU previously (Mazhari, 2012; Reed et al., 2015; Saville et al., 2010), and adds to the suggestion that SMA, and perhaps problematic digital behaviour more generally, may be related to impulse control issues (Cudo & Zabielska-Mendyk, 2019; Tsai et al., 2020; Vargas et al., 2019). The relationship suggests that a focus of treatment should be based around tackling impulse control and short-term decision making (see also Cudo & Zabielska-Mendyk, 2019; Vargas et al., 2019).

That no effect of SMA on either Stroop or WCST performance, which relate to attention and attentional switching (Experiments 1 and 2), suggests any effects on these aspects of executive function are smaller than those relating to impulsivity. The failure to note a strong effect of SMA on Stroop or WCST performance may be connected with the use of neutral words in these tasks; however, that no effect was noted in the social media contexts suggests this cannot be the full explanation. Indeed, when such an effect has been found previously, it has been when using computing-related words (Jeromin et al., 2016). Previous research using the IGT employing neutral stimuli also is mixed with respect to PIU (cf. Lin et al., 2019; Xu, 2012). That exposure to social media made impulsivity worse (Experiment 2), is consist with findings on exposure to the internet making impulsivity worse in those with PIU (Reed et al., 2015). It is also consistent with the finding that the association between SMA and poor inhibition on the Go-NoGo task is stronger when the cues were social media related (see also Gao et al., 2019; Zhou et al., 2012). Thus, there appears to be an interaction between the presence of SMA and exposure to social media cues in making cognitive performance related to impulsivity and inhibition worse. This relationship should be explored in more detail in further studies, as it suggests that any treatment of impulse control may be targeted on contexts in related to social media, and that this may not be a generalised trait in these individuals.

In addition to the effects of SMA on impulsivity, Experiment 1 noted that some aspects of memory performance, were poorer for those with SMA. This finding has been seen in other addictions (Weinborn et al., 2011), and for PIU (Hadlington, 2015; Sharifian & Zahodne, 2020). As the current findings with respect to EF tasks suggest impulse control and reward-sensitivity are the key issues, then it may be that any memory performance impairments, especially memory involving planning, such as prospective memory and everyday memory, may be associated with inhibitory or impulsive behaviours, rather than attentional issues (see Gladwin, Jewiss, Banic, & Pereira, 2020). The current findings do not permit further speculation, but this could be explored further, a sit clearly has some implications of memory training with this population.

There are a number of limitations to the present series of studies that should be mentioned. These data are based on experimental studies conducted over a short period of time, and investigation of impulsivity and SMA will need to be conducted longitudinally. In addition, the participants were either recruited through social media platforms, or were undergraduate students. Although both of these sampling strategies would tend to identify those likely to show such problems, they may not be totally representative of the population, and a wider sample of participants would add generality to the findings. The measures of social media addiction did rely on self-report, which is a reasonable way to examine such an issue; however, the use of additional objective measures like usage of social media, or informant reports, would add to our understanding of these issues.

In summary, there does appear to be strong reason to suggest a link between SMA and impaired cognitive function. This corroborates the results of several previous studies, and suggests that impact of SMA is not limited to emotional and social functioning.

Credit author statement

PR - Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing – original draft; Writing – review & editing

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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