

Individual Differences and Correlates of Highly Superior Autobiographical Memory

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Abstract

Highly superior autobiographical memory (HSAM) is a recently identified ability that has been difficult to explain with existing memory science. The present study measured HSAM participants' and age/gender matched controls' on a number of behavioral measures to test three main hypotheses: imaginative absorption, emotional arousal, and sleep. HSAM participants were significantly higher than controls on the dispositions absorption and fantasy proneness. These two dispositions also were associated with a measure of HSAM ability within the hyperthymia participants. The emotional arousal hypothesis yielded only weak support. The sleep hypothesis was not supported in terms of quantity, but sleep quality may be a small factor worthy of further research. Other individual differences are also documented using a predominantly exploratory analysis. Speculative pathways describing how the tendencies to absorb and fantasize could lead to enhance autobiographical memory are discussed.

Keywords. Autobiographical Memory, HSAM, Hyperthymia, Absorption, Fantasy Proneness, Emotional Arousal, Sleep

Absorption and Fantasy Proneness as Surprising Explanations for Highly Superior
Autobiographical Memory

Highly superior autobiographical memory (HSAM; also known as hyperthymesia) is still quite a mystery. It is an ability that only recently has been scientifically studied (Parker, Cahill, & McGaugh, 2006; LePort et al., 2012; Ally, Hussey, & Donahue, 2013; Patihis et al., 2013). HSAM involves a detailed and accurate recall of personal events, dates, and news events from long term memory. HSAM individuals can recall events on almost every day, usually from mid-childhood onwards. Some report they can remember in this fashion as far back as five years old. The first documented modern case was first published in 2006 (Parker et al., 2006), although there was a possible case documented as far back as 1871 (Henkle, 1871). It is a phenomenon that is difficult to explain in the light of decades research that demonstrates the fallibility and reconstructive nature of human memory (e.g. Barlett, 1932; Loftus, 2005).. One mystery is the apparently very large store of autobiographical memory these HSAM individuals have, relative to other people . What is different about HSAM individuals that results in such divergent memory ability in this domain? This study looks at behavioral measures to investigate how HSAM individuals differ from ordinary individuals.

Parker et al. (2006) were the first to document a case of what they called hyperthymestic syndrome (to be renamed later as HSAM). Their one participant, given a pseudonym AJ, reported that remembering her personal past ruled her life in a burdensome way. She reported her memory ability to be accurate and reliable in a fashion that was almost automatic. She excels specifically in remembering events and knowledge that is personally relevant to her. She reported remembering dates from the past exceedingly well, including the day of the week, and events from that day. She described that she had a good memory as a young child, but at age 8

her memory improved such that she could remember almost every day. After age 14 her recall improved further so that she reports being able to remember every day. From age 10 onwards she kept diaries, but she reported that she rarely looked at those diaries later. When given 10 dates after 1977 AJ was able to correctly name the significant news event that happened on those dates. Conversely, when given significant news events in that period, she was able to accurately recall the date on which that happened. The researchers used her diaries to test her recall of dates and personal events that happened to her on a recurring event (Easter), chosen without forewarning by the researchers, and her performance was almost perfect. This case study formed the foundation of superior autobiographical memory studies that followed, but it also raised questions as to whether there had been previous cases that had gone unnoticed.

It is uncertain whether there were cases of HSAM before AJ, but one good candidate is a single case described by Henkle in 1871. Other types of superior memory had been described before the case of AJ (see next subheading), but Henkle's (1871) case "Daniel McCartney" (DM) is the closest precedent of something akin to HSAM. DM, similar to today's HSAM individuals, was able to recall the dates extremely well from age 9 onward as well as events on those dates (such as the weather). Like AJ, DM reported being able to remember most dates—not every day in earlier childhood, but every day from mid childhood onwards. DM, like AJ, reported being able to recall the day of the week on any date, and details such as news events (e.g. the inauguration of General Taylor, the hanging of John Brown) and personal events (e.g. cutting a wood stove for someone, or attending a meeting in Iberia).

Following the Parker et al. (2006) description of AJ, more people claiming to have HSAM came forward, and some of those were subsequently categorized as HSAM and were tested further. LePort et al. (2012) described 11 HSAM individuals, including AJ, and described

how they were identified, their structural brain scans, their performance on standard laboratory memory tests, and a number of other measures. They identified HSAM participants using a Public Events Quiz and a 10 Date Quiz, the same means of categorization used in this study (detailed below at the next subheading). The structural MRI brain scans of HSAM participants have shown some areas that are thought to play a role in autobiographical memory are different than age matched controls. As LePort et al. (2012) point out, the structural differences in the temporal gyri and pole, the anterior insula, and the hippocampal gyrus, are regions are thought to be part of an autobiographical memory network. These differences may or may not be indicative of a causal relationship between differing brain morphology and increased memory ability (or vice versa). These are, however, interesting clues. If there is a valid connection between anatomy and memory performance in HSAM it is uncertain whether the brain morphology differences caused the superior memory ability (nature) or the memory processing is causing the brain to change (nurture), or both.

HSAM abilities are distinct from previously described superior memory individuals (e.g. Luria, 1968; Hunt & Love, 1972; Ericsson & Chase, 1982; Gordon, Valentine, & Wilding, 1984; Wilding & Valentine, 1997) who typically rely upon practised mnemonics to remember unusually long lists of domain-specific data, yet remain average in their ability to retrieve autobiographical information. In contrast to these superior memory cases, HSAM individuals do not tend to use mnemonics, rote practice, and do not uniformly report using memory rehearsal techniques. HSAM individuals exhibit average scores on short-term memory tasks unrelated to autobiographical memory. In addition, they recall their past in great detail in a way that seems almost automatic. Some HSAM individuals have, however, kept diaries, and have reported rehearsing their memory of dates and events as well as categorizing and cataloging their

experiences on certain dates in their minds. Importantly, not all HSAM participants have reported using these techniques, so it is unclear what they have in common that may be enhancing the memory.

Searching for Clues in Individual Differences

In an attempt to understand why HSAM individuals have the ability they do, one can find clues by examining individual differences—how they differ from people without HSAM. The question is: What is different about HSAM individuals, compared to people with normal memory, that predisposes them to consolidate autobiographical memory so strongly? Below is a brief review examining whether there is any evidence of a relationship between an array of individual differences and autobiographical memory accuracy. Many of the individual differences chosen for consideration in this study that have previously been found to be associated with some type of memory measure (accuracy or error measures), or are measures that potentially could be important from a theoretical standpoint.

The field of autobiographical memory research is broad, as is the field of personality and emotion, so here the specific focus here is on areas that might shed light on HSAM and potential individual difference correlates. First, a imaginative-absorption hypothesis of autobiographical memory consolidation is examined. Later, an emotional arousal hypothesis and a sleep consolidation hypothesis are outlined.

The Imaginative-Absorption Hypothesis

Possible correlates of HSAM could be personal dispositions and tendencies towards certain memory-related behaviors, i.e. personality factors that might result in multiple stronger initial encoding or multiple re-encoding that aids consolidation of autobiographical events. For purposes of clarity, tendencies to become emotionally involved in personal events are discussed

in the later section on emotional arousal. Other tendencies, such as the disposition to pay close attention to new experiences or perhaps the tendency to remember and re-remember personal events, are discussed next.

Absorption. The “absorption” (Tellegen Absorption Scale; TAS) construct attempts to capture “openness to absorbing and self-altering experiences” (Tellegen and Atkinson, 1974; p. 268). Absorption, related to hypnotizability, is the “disposition for having episodes of ‘total’ attention that fully engage” perceptive and imaginative resources, and it results in a heightened sense of reality towards the object of attention (p. 268). Openness to absorbing experience that impacts on the self (autobiographical) could lead to a deeper attentive processing of such experiences, and perhaps stronger autobiographical memory. Therefore, we might expect people with HSAM to get absorbed in events that involve some connection to their self. Getting absorbed into new experiences, and altered by them, might be a recipe for encoding more autobiographical memory for longer.

However, absorption has been implicated with memory errors in previous research when misleading information is introduced. For example a study by Eisen and Carlson (1998) that found those scoring higher on absorption had more false memory from misinformation. Likewise, Patihis et al. (2013) found that absorption could be one of the mediators of false memory from misinformation in HSAM individuals, compared to controls. These findings could be explained by those higher on absorption visualizing the misinformation more, processing it more, and therefore encoding the misleading information well.

Platt, Lacey, and Finkelman (1998) found that absorption was negatively correlated with a measure of autobiographical memory accuracy. Their measure of autobiographical memory involved asking participants where they were, what they were doing, and who told them, when

they heard the news of the OJ Simpson case. Participants were asked the evening of the verdict, and then again 6, 12 or 18 months later. Indeed, accuracy did falter with time, and this was especially true in those scoring high on absorption. Given the possibility disparity between the possibility that increased absorption and “total” attention towards new experiences might improve the encoding and consolidation of autobiographical memory, and studies that have shown absorption to be associated with memory errors, it remains an open question whether absorption will relate to performance in autobiographical accuracy measures in the present study.

A subset of questions on the Tellegen Absorption Scale measure synesthesia, the tendency of various senses to be experienced together. Because synesthesia has been present in some past case of superior memory, for example Luria’s (1968) subject S., it is of interest whether synesthesia is also associated with HSAM.

Fantasy Proneness. The Creative Experiences Questionnaire (CEQ; Merckelbach, Horselenberg, & Muris, 2001; Merckelbach, Muris, & Rassin, 1999) is a measure of fantasy proneness (for earlier work on this construct see Lynn & Rhue, 1986; Wilson & Barber, 1983). Fantasy proneness is a construct refers to the tendency to fantasize in a deeply imaginative way that can feel real. It is a construct used to explain hypnotizability, and has some overlap with the construct absorption (Kihlstrom, Glisky, & Angiulo, 1994), hence the pairing of these two constructs into a single “imaginative-absorption” hypothesis.

Some studies have shown fantasy proneness to be associated with some types of memory errors, while others have shown increases in accurate recall. For example, Horselenberg, Merckelbach, van Breukelen, and Wessel (2004) found that participants higher on fantasy proneness (CEQ) were less able to discriminate real autobiographical events that they themselves had documented 6 months earlier from false events. Likewise, Spanos et al. (1994) reported that

fantasy prone individuals were more likely to produce detailed accounts under hypnosis of memories of past lives. However, in Merckelbach (2004) fantasy proneness was implicated in both memory accuracy and errors: fantasy prone individuals created richer stories of childhood experiences in both true and fabricated stories. Therefore, fantasy proneness might in some circumstances be beneficial in remembering content for events for which no misleading information had been given. This might be possible if the fantasizing occurs in relation to actual life events that have just occurred. Given these findings, it is an open question as to whether fantasy proneness would help or hinder the type of autobiographical recall in which HSAM individuals excel.

The Emotional Arousal Hypothesis

Another possible explanation of HSAM is that enhanced emotional arousal helps encode and consolidate autobiographical memory. The question is whether HSAM individuals consistently have a more emotional reaction to autobiographical events, compared to people without HSAM. There is evidence that strong emotional arousal can help encode memory (Cahill & McGaugh, 1995) and that one of the mechanisms for this is epinephrine that is released during the consolidation period following the event (in animals: Gold & Van Buskirk, 1975; and humans: Cahill & Alkire, 2003). Cahill and Alkire (2003) not only observed that post-event injection of epinephrine led to stronger performance in a memory test 1 week later, but they also observed that the emotional arousal at the time of encoding enhanced memory. These findings, when combined with other findings pointing to a similar conclusion (e.g. Christianson & Loftus, 1987) indicate that emotional arousal at the time of the event, and afterwards, can strengthen memory. In addition, Schmolck, Buffalo, and Squire (2000) found that autobiographical memory accuracy surrounding the OJ Simpson verdict 32 months after the verdict significantly correlated

with the strength of the participant's emotional reaction to the event. These findings suggest that increases in variables related to emotional arousal during and after the event would be relevant measures to investigate when comparing HSAM to control participants.

Anxiety. Anxiety involves a state of vigilance and unrest and nervous behavior without a clear actual threat being present. Indeed, this excited state has been linked to epinephrine in that epinephrine administered to people can lead to anxiety and its physical feelings (Basowitz, Korchin, Oken, Goldstein, & Gussack, 1956; Breggin, 1964; Hosseini & Tadayon, 2013). Indeed Hosseini and Tadayon (2013) found a strong correlation ($r = .85$) between epinephrine and anxiety. So there is theoretical reason to hypothesize that anxiety, through the mechanism of epinephrine levels may lead to strong consolidation of memory. If epinephrine levels are high for a lot of the time in highly anxious people, perhaps that could explain people who remember most of their past. Combine this with preliminary data (LePort et al., 2012) that HSAM individuals tend to be high on a scale of subclinical obsession and compulsive tendencies, which is related to a disorder that is classified as an anxiety disorder (OCD), then there is further reason to investigate anxiety levels in HSAM individuals.

There is some research on aspects of autobiographical memory and anxiety. For example, Burke and Mathews (1992) found that people with generalized anxiety disorder recalled more personal memories when given a word that cued and anxiety evoking memory. There has also been research that has shown that those experiencing more anxiety *about* an event (as opposed to generalized trait anxiety) were more consistent in remembering flashbulb-type news event detail, such as 9/11 (Conway, Skitka, Hemmerich, & Kershaw, 2009; see also Er, 2003). From the studies above, it is clear that anxiety is a relevant measure to investigate within the broader framework of the emotional arousal hypotheses.

Empathy. Robinson and Swanson (1990) wrote that the central function of autobiographical memory is to maintain and extend relationships, an ability that is also necessary for developing empathy. Indeed, this relationship has been explored empirically: Pohl, Bender, and Lachmann (2005) measured participants empathy (using the Interpersonal Reactivity Index; Davis, 1983) and utilized an autobiographical memory measure that asked whether and how well they remembered each of 8 personal events (e.g. 18th birthday) and 3 important news events (e.g. Chernobyl disaster). They found that autobiographical memory performance and empathy were positively related, $r = .34$. This suggests a link between autobiographical memory and empathy that could be explored further with verifiable event details. Given the theoretical and empirical data empathy is another variable of interest under the general heading of the emotional-arousal hypothesis.

Emotional Detachment. High empathy and low emotional detachment are similar, in that empathy is related to feeling for others and low detachment can also mean an emotional desire for others. However, they differ in that detachment can also mean how detached one feels towards life in general and events (rather than people). It seems possible, therefore, that being detached from the meaningful events of one's life could impede the development and maintenance of autobiographical memory. Related to this hypothesis, Addis, Moscovitch, Crawley, and McAndrews (2004) used an emotionality scale that ranged from "detachment; no emotional experiences" to "intense emotional experiences," and found that those participants that scored lower on the scale (detached) had lower autobiographical memory detail ratings than those high on the scale ($r = .54$). This study gives reason, when combined with the other findings reported above, give reason to explore this relationship further.

High Arousal Emotions. In keeping with the literature discussed above on the relationship between emotional arousal and enhanced encoding of memory, it is possible that those people who react most strongly to an event on measures of high arousal emotions might develop better autobiographical memory for those events. Indeed, Talarico, LaBar, and Rubin (2004) found that emotional intensity was their largest predictor of autobiographical memory measures. Emotional intensity was associated with more self-reported recollections, vividness, and rehearsal of autobiographical memory. Although these measures were not verified, research in the area of flashbulb events (where some of the news events are verifiable) reinforce the idea that emotion can enhance encoding strength (Brown & Kulik, 1977; Conway et al., 1994; Finkenauer et al., 1998; Luminet et al., 2004). However, it should be noted that even such flashbulb events are nevertheless subject to memory errors.

Because HSAM individuals seem to have strong memory for news events (LePort et al., 2012) if we compare people's report of high arousal emotions *towards the same news event* (for example 9/11) then we may find HSAM individuals score higher.

The Sleep Consolidation Hypothesis

Encoding and consolidation processes of memory occur during sleep, and sleep is helpful and necessary for the maintenance of normal memory (Stickgold, 2005; Stickgold & Walker, 2005; Walker & Stickgold, 2004). For example, one study found that participants taking a nap after the event stage of a procedural memory task improved memory accuracy after the nap (Mednick, Nakayama, & Stickgold, 2003). This is true not only with procedural memory, but also with declarative and episodic memory several studies have also found effects of sleep on memory accuracy (e.g., Dumay & Gaskell, 2007; Frenda, Patihis, Loftus, Lewis, & Fenn, 2014).

Given these results, it is possible that consistently getting enough sleep may lead to better memory for personal events.

Murre, Kristo, and Janssen (2013) investigated the relationship between autobiographical memory accuracy and self-reported naturally occurring sleep quantity and quality.. Murre et al. (2013) found that sleep *quality* was associated with autobiographical memory performance at longer intervals (4–6 weeks) but not at shorter retention intervals (less than 2 weeks). Sleep *quantity* was not associated with memory performance. The quality of sleep may therefore help the deep consolidation of autobiographical memory over a period of many weeks. This could be of interest because HSAM individuals outperform people with average memory much more on tasks involving longer term memory than shorter term memory (see LePort et al., 2012).The consolidation process during sleep is important in forming lasting autobiographical memories, and therefore sleep quantity of quality are a relevant variables to examine as part of an open hypotheses..

Summary. There are a number of possible variables that couldbe associated with HSAM. These possible variables are linked to plausible explanations that include emotional arousal in experiences as they happen, deep absorption in new experiences, heightened arousal in the consolidation period after the event, and greater consolidation during sleep. It is difficult to predict which of these might be correlates of enhanced autobiographical memory, because there is more than one plausible explanation, and it may be a phenomenon that has more than one correlate. In addition to these hypothese-related variables, I document other variables using a predominantly exploratory approach to investigate other measures of interest, such as correlates of cognitive ability (e.g. SAT scores and rationality measures), demographic variables, handedness, and beliefs about memory. In this article I examine how individual difference

measures vary between HSAM and control participants, as well as how they vary with autobiographical ability within the HSAM group.

Method

Participants

Twenty HSAM individuals and 38 age- and gender-matched controls from the general public (± 4 years of age) participated (as in Patihis et al., 2013). Each HSAM participant was matched to one or two age- and gender-matched controls. Participants were paid \$40 each for about 3 hours of participation. The age range was 21 to 62 with a mean of 38.8 ($SD = 10.5$), with 74.1 % male and 25.9 % female, and due to matching there were statistically similar numbers within HSAM (75.0% male; $M_{age} = 38.6$) and control groups (73.7% male; $M_{age} = 39.0$). Within the HSAM group ethnicity was distributed as Caucasian 95% (19) and 5% (1) Middle Eastern (Persian). In the control group ethnicity was distributed as Caucasian 76.3 % (29), Latino or Hispanic 10.5 % (4), Asian 7.9 % (3), Middle Eastern 2.6% (1), and Black 2.6% (1). Sample size was determined by the number of HSAM individuals willing to participate (20 chose to participate out of the 30 HSAM individuals discovered at the time of recruitment), and a limit of matching no more than 2 control participants to each HSAM participant. Internal Review Board approval (UC Irvine IRB; HS#2011-8038; PI: L. Patihis) was granted to conduct this study with human subjects.

Materials

Identification of HSAM. The identification of HSAM in the participants of this study was performed prior to the present study's data collection, and is described in LePort et al. (2012) and Patihis et al. (2013). HSAM was identified based on a high score on a Public Events Quiz (above 50 % correct), and then a high score (above 65 % correct) on a 10 Dates Quiz.

The Public Events Quiz contained two types of questions: 15 asked for the exact date of a given significant public event that took place within the individual's lifetime. The other 15 question asked for the significant public event that took place on a given date. In addition, for all 30 questions, individuals were asked to state the day of the week the date fell on. The significant public events given were selected from five different categories: sporting events, political events, notable negative events concerning famous people, and holidays.

The 10 Dates Quiz consisted of 10 computer generated random dates, selected from the time period ranging from when the participant was age 15 to the day of testing. Individuals were asked to provide three different categories of information for each of the 10 dates generated: (a) the day of the week; (b) a description of a verifiable event (i.e. any event that could be confirmed via a search engine) that occurred within one month of the generated date; and (c) a description of a personal autobiographical event the individual participated in on that date. One point was awarded for the correct day of the week, for giving a verifiable event confirmed as true, and for giving a personal autobiographical event. A maximum of three points per date could be achieved (30 points total). This very conservative measure was taken so as to ensure that an HSAM participant was proficient at accurately identifying events, whether in the public or private domain, and the days of the week they occurred.

On average, controls (none claiming to have HSAM) scored 11.1% on the 10 Date Quiz and 12.6% on the Public Events Quiz. HSAM individuals showed unusually high scores on both the Public Events Quiz and the 10 Dates Quiz, with a minimum of a score of 53.4% on the Public Events Quiz and a minimum of 69.0% on the 10 Date Quiz. As a result of testing many participants who thought they might have HSAM 30 had passed the criteria for HSAM at the

time of recruitment (2012) and of these 20 were recruited. We excluded one participant from this article's analysis due to visual impairment.

In the present study, the 10 Dates Quiz score is taken to be the best measure of HSAM ability, as compared to the Public Events Quiz, for a number of reasons. One reason for this is the 10 Dates Quiz gives the participant the freedom to recall a public event they actually experienced within a month of a randomly chosen date. In the Public Events Quiz the potential confound is that the participant's did not hear about or experience the news story that the researchers ask about. In the Public Events Quiz the date is not randomly generated, rather it is prescribed by major new events in five categories. Whereas the 10 Date Quiz did not restrict news event categories, the Public Events Quiz score could partially reflect specific ability in one or more of the five categories, e.g. sports events. In contrast to the Public Events Quiz that involved only news events, the 10 Dates Quiz also measured participants' ability to produce a personal autobiographical event from a randomly selected date. For these reasons, in this study the 10 Dates Quiz is used in analyses as a measure of HSAM ability.

A brief summary of individual differences measures used that may not be self-explanatory is given here.

Hypothesis-Related Variables.

Absorption. The Tellegen Absorption Scale (Tellegen & Atkinson, 1972) was the scale used to measure the disposition to become absorbed into new experiences. The 34 items on this scale are shown in Table 1. Participants were asked to state how often various experiences happened to them, on a scale that ranged from 0% = *never* (coded 0) to 100% = *always* (coded 10). Each of the question's score (range 0 to 10) was summed to give the overall absorption score.

Synesthesia Sub-scale. The items used in a synesthesia subscale (from the Tellegen Absorption Scale; see Table 1) were: item 10 “Textures -- such as wool, sand, wood -- sometimes remind me of colors or music”; item 27 “Some music reminds me of pictures or changing color patterns; and item 33 “I find that different odors have different colors.”

Fantasy Proneness. The Creative Experiences Questionnaire consisted of 25 items related to the fantasy proneness construct. Participants answered “yes” (coded 1) or “no” (coded 0). The overall fantasy proneness measure was obtained by summing the yes responses together.

Anxiety and Emotional Detachment Traits. The Swedish Universities Scale of Personality (SSP; Gustavsson, Bergman, Edman, Ekselius, von Knorring, & Linder 2000) was used to measure the subscale traits of psychic trait anxiety, somatic trait anxiety, and trait emotional detachment. Psychic trait anxiety is characterized by “worrying, anticipating, lacking self-confidence,” whereas somatic trait anxiety involves “autonomic disturbances, restless, tense” (p. 219). Trait detachment is described as “avoiding involvement in others, withdrawn” (p. 219).

Empathy. The Basic Empathy Scale (BES; Jolliffe & Farrington, 2006) is a 20 item measure used to measure both cognitive empathy: “the capacity to *comprehend* the emotions of another”) and affective empathy: “the capacity to *experience* the emotions of another” (p. 589). Participants rated how much they agreed to various empathy-related questions on a 5 point Likert scale from 1 = *strongly disagree* to 5 = *strongly agree*. These scores were summed into subscores for cognitive and affective empathy.

High Arousal Emotions. In Session 1, participants rated how often they felt on each of the following high-arousal emotions: “Stressed”, “Tense,” and “Jumpy” in the week following the September 11th, 2001 terrorist attacks. The Likert-type scale ranged from 1 = *never* to 10 =

all the time. These three items were summed to produce the overall score for high-arousal emotions.

Sleep Diaries. The sleep diary was a self-reported measure filled in every morning for one week. Items included the time participants went to bed and got up, the time it took to fall asleep, night-time awakenings, how long they slept, and daytime naps.

Exploratory Variables.

Handedness. The 12-item version of Oldfield's (1971) handedness scale was used to assess tendencies toward right-handedness or left-handedness, a scale that assessed to use the left or right limbs of to perform various dexterity tasks. For example, questions asked what hand is preferred when using a spoon, a toothbrush, and so on. The scale for each question had anchors: *1 = Strong left hand preference, 2 = Left hand preference, 3 = Indifference, 4 = Right hand preference, and 5 = Strong right hand preference.*

SAT Scores. SAT scores were taken as a proxy measure of intelligence because they correlate highly with the psychometric measure for general intelligence *g* (Frey & Detterman, 2004; $r = .82$). It was a convenient and relatively cohort consistent measure to use because each subscale of the SAT test for all the participants had been normed approximately around an average of 500 from 1972 to 2012 (College Board, 2014). The SAT total score was attained by adding the Math and Reading Subscales. A new writing subscale was introduced to the SAT in 2005 (College Board, 2014) so to keep scores comparable across age cohorts this subscale was not used when calculating the SAT total score.

Critical Thinking. Nine items that measure various aspects of critical thinking ability were compiled using West, Toplak, and Stanovich, (2009) as a guide. See Supplementary Materials for the items and for further citations. These items involved multiple choice answers,

and were scored 1 if correct, 0 if incorrect. The critical thinking score was the sum of those nine items.

Flexible Thinking. The Flexible Thinking Scale (FTS; Stanovich & West, 1997) was used as a measure to determine the degree to which participants have flexible and “actively open-minded thinking” (p. 342). The 10 items in this scale were rated on a scale from 1 = *disagree strongly* to 6 = *agree strongly*. Various items capture different aspects of flexible thinking, tapping into the following dispositions: reflectivity (4 items), willingness to consider evidence contradictory to beliefs (1 item), willingness to consider alternative opinions and explanations (2 items), and a tolerance for ambiguity and postponing closure (3 items).

Procedure

Subjects participated remotely at a place of their choosing (usually at their home on their own computer), with a research assistant connected to them via Skype video-chat or phone for the entirety of both Session 1 and 2. Participants were instructed to have the computer on a desk, and themselves be sitting on a chair. Researchers advised the participants before the study commenced on how to avoid distractions and interruptions. Individual differences measures were filled out in Session 1, and in Session 2. Sleep diaries were completed every morning for seven days in the week between Session 2. In Session 2 they also completed some memory distortion tasks as reported in Patihis et al. (2013).

Results

In a predominantly exploratory analysis how HSAM individuals differed from controls on a variety of measures was examined. Within the exploratory analysis, several plausible correlates were identified as plausible hypotheses, although these hypotheses were generally open questions due to the potential complexity of the phenomena. Due to the inevitable low

power afforded by the rare and small sample of HSAM individuals, no Bonferroni corrections are made in order to avoid Type 2 statistical errors (such corrections would have rendered effect sizes as large as $r = .5$ as non-significant). To avoid large number of correlational analyses between HSAM ability and individual differences measures, only measures that showed significant or marginal differences on the between-groups analysis were examined to see how they vary with HSAM ability (10 Dates Quiz).

Testing the Imaginative Absorption Hypothesis

Absorption. HSAMs scored higher ($M = 90.4$, $SD = 19.9$, 95% CI [81.7, 99.1]) on the Tellegen Absorption Scale than controls ($M = 72.6$, $SD = 16.9$, 95% CI [67.2, 78.0]), $t(56) = 3.57$, $p = .001$, Cohen's $d = .96$. This comparison is shown in Figure 1 below.

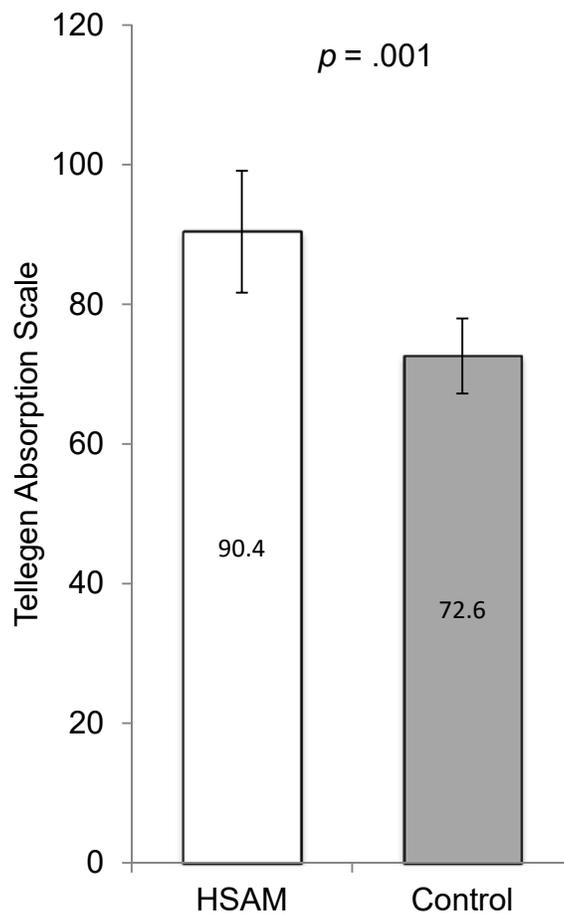


Figure 1. Mean scores on the Tellegen Absorption Scale in HSAM and control groups. The mean of the summed scores for absorption in HSAM participants was statistically significantly higher than control participants. Error bars represent 95 % confidence intervals.

Finding this group difference prompted an analysis of the relationship between absorption and HSAM ability (as measured by the 10 Date Quiz) within HSAM participants.

That relationship is shown in Figure 2 below.

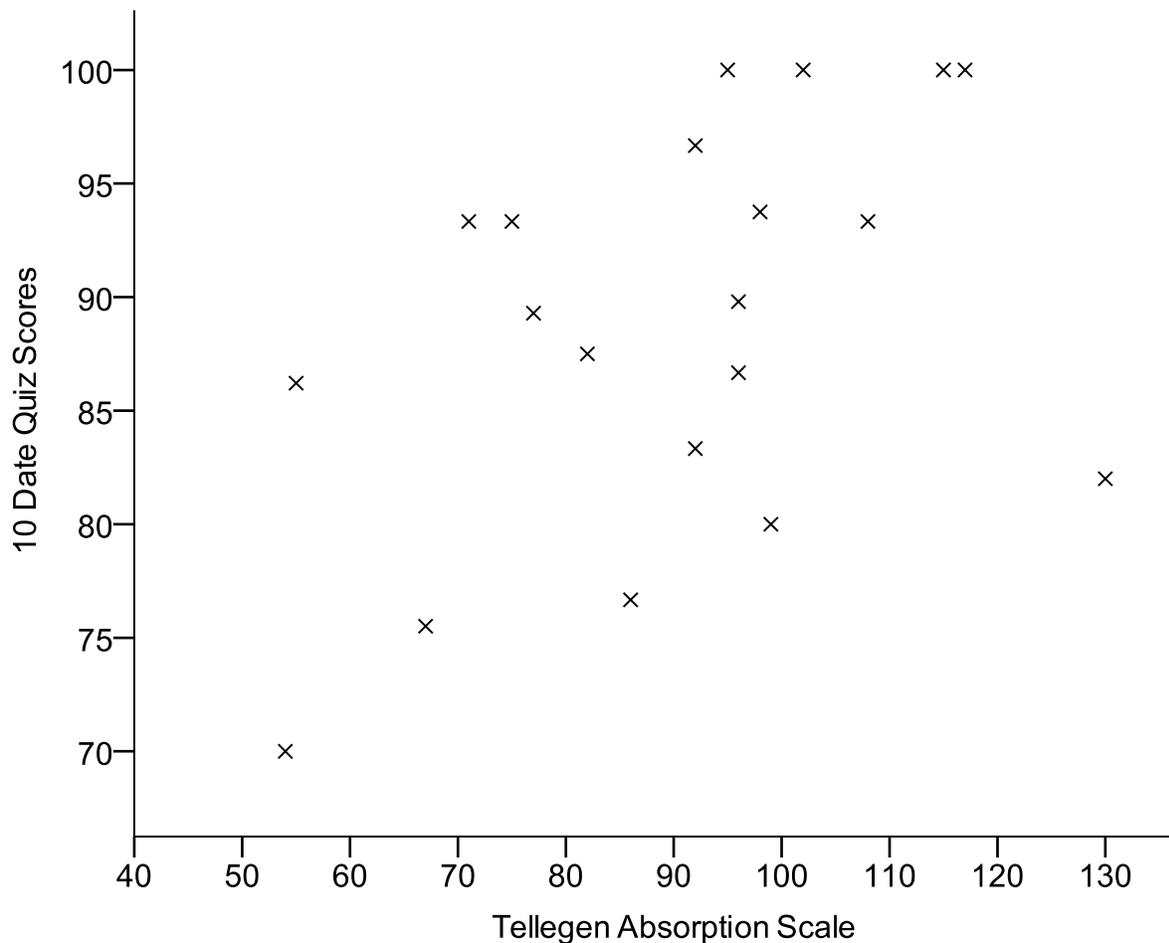


Figure 2. Within HSAM individuals: The statistically significant association between absorption and HSAM ability (10 Dates Quiz), Pearson $r = .45$, $p = .047$.

Fantasy Proneness. As shown in Figure 3 below, HSAM individuals scored higher on the creative experiences questionnaire ($M = 11.25$, $SD = 4.85$, 95% CI [9.13, 13.37]) compared to controls ($M = 8.08$, $SD = 4.53$, 95% CI [6.64, 9.52]), $t(56) = 2.42$, $p = .019$, $d = .65$.

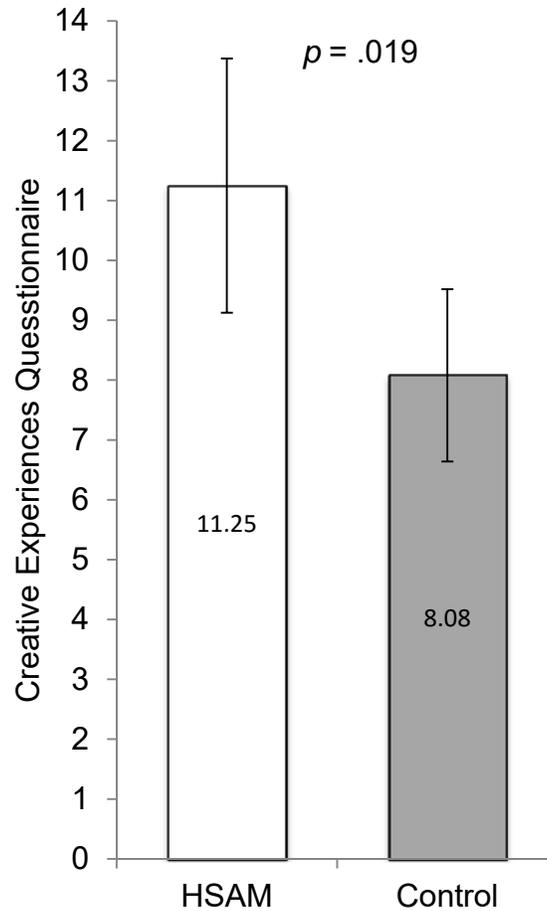


Figure 3. Mean scores on the creative experiences (aka fantasy proneness) in HSAM and control groups. The mean of the summed scores for fantasy proneness in HSAM participants was statistically significantly higher than control participants. Error bars represent 95 % confidence intervals.

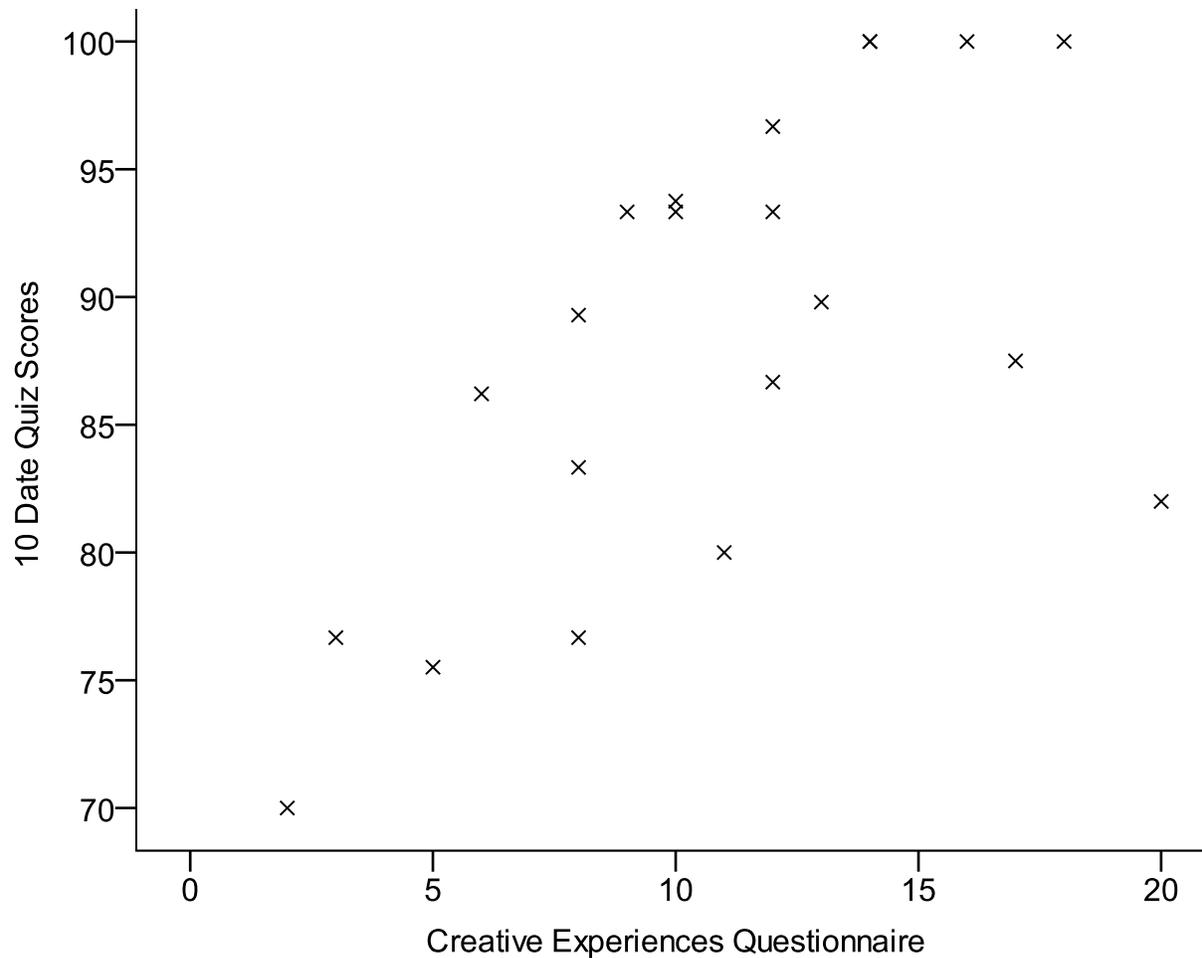


Figure 4. Within HSAM individuals: The statistically significant association between fantasy proneness (CEQ) and HSAM ability (10 Dates Quiz), $r = .58$, $p = .008$.

Comparing Absorption to Fantasy Proneness. Absorption was highly related to the fantasy proneness, $r = .82$, $p < .001$. This created problematic multi-collinearity and inflated standard errors in a regression model that included both constructs as predictors, so the bivariate relationships are used here. To summarize these bivariate results, both absorption and fantasy proneness were reliable predictors of HSAM. Absorption had the larger Cohen's d than fantasy proneness when comparing HSAM to control groups, whereas fantasy proneness had a higher bivariate correlation in the association with HSAM ability (10 Date Quiz score) within HSAM individuals.

Possible Construct Confounds with HSAM in Absorption and Fantasy Proneness.

To investigate whether the relationship between absorption and HSAM and fantasy proneness and HSAM were confounded by items other than the core constructs, a secondary analysis of items was performed. One possible confound is the fact that both the Tellegen Absorption Scale and the Creative Experiences Scale both have 2 items that mention memory. When removing the 2 items referring to memory from the summed overall score for absorption and fantasy proneness the relationship between HSAM and these constructs remained of similar magnitude as before. After removing the memory items the correlation with the 10 Dates Quiz was $r = .45$ ($p = .048$) for absorption and $r = .54$ ($p = .013$) for fantasy proneness. Further item by item analysis shown in Table 2 confirmed that items in the CEQ directly conveying the tendency to fantasize (e.g. items 10 & 11) were significantly higher in HSAM compared to control individuals, *and* was associated with HSAM ability also.

Synesthesia-Related Items. Items 10, 27, and 33 in the Tellegen Absorption Scale (see Table 1) all captured synesthesia: which is the triggering of one sense by other senses. The items captured the triggering of color/music by texture, color by music, and color by odor. Summing these 3 items gave a synesthesia total score. On this synesthesia variable, HSAM participants were marginally higher ($M = 6.00$, $SD = 3.13$) than controls ($M = 4.63$, $SD = 1.85$), unequal variances test $t(26.2) = 1.80$, $p = .084$ ($d = .56$). Synesthesia was not significantly associated with 10 Date Quiz Scores within HSAM participants ($r = .25$, $p = .280$).

A stronger predictor than synesthesia was a related but different question on the TAS. The item (“different colors have distinctive and special meanings for me”) captured the tendency to find meaning in color. On this item HSAM participants ($M = 2.90$, $SD = .97$) were

significantly higher than controls ($M = 2.16$, $SD = .97$), $t(56) = 2.77$, $p = .008$ ($d = .74$). This item also was associated with 10 Date Scores within HSAM participants, $r = .55$, $p = .013$.

Table 1. *Tellegen Absorption Scale: Each Item's Effect Sizes (r) Indicating How HSAM and Controls Differ and Associations with HSAM ability (10 Date Quiz).*

	HSAM vs Control	HSAM 10 Date Quiz
1. Sometimes I feel and experience things as I did when I was a child.	.572***	-.169
2. I can be greatly moved by eloquent or poetic language.	.343**	-.060
3. While watching a movie, a TV show, or a play, I may become so involved that I may forget about myself and my surroundings and experience the story as if it were real and as if I were taking part in it.	.114	.472*
4. If I stare at a picture and then look away from it, I can sometimes "see" an image of the picture almost as if I were still looking at it.	.285*	.062
5. Sometimes I feel as if my mind could envelop the whole world.	.395**	.375
6. I like to watch cloud shapes change in the sky.	.034	.231
7. If I wish I can imagine (or daydream) some things so vividly that they hold my attention as a good movie or story does.	.363**	.192
8. I think I really know what some people mean when they talk about mystical experiences.	.345**	.228
9. I sometimes "step outside" my usual self and experience an entirely different state of being.	.313*	.323
10. Textures -- such as wool, sand, wood -- sometimes remind me of colors or music.	.289*	.217
11. Sometimes I experience things as if they were doubly real.	.242	.119
12. When I listen to music I can get so caught up in it that I don't notice anything else.	.229	.503*
13. If I wish I can imagine that my body is so heavy that I could not move it if I wanted to.	-.058	.354
14. I can often somehow sense the presence of another person before I actually see or hear her/him.	.317*	.087
15. The crackle and flames of a wood fire stimulate my imagination.	.030	.420
16. It is sometimes possible for me to be completely immersed in nature or in art and to feel as if my whole state of consciousness has somehow been temporarily altered.	.159	.502*
17. Different colors have distinctive and special meanings for me.	.347**	.545*
18. I am able to wander off into my thoughts while doing a routine task and actually forget that I am doing the task, and then find a few minutes later that I have completed it.	.087	.318
19. <i>I can sometimes recollect certain past experiences in my life with such clarity and vividness that it is like living them again or almost so.¹</i>	.652***	.289
20. Things that might seem meaningless to others often make sense to me.	.594***	.182
21. While acting in a play I think I could really feel the emotions of the character and "become" her/him for the time being, forgetting both myself and the audience.	.318*	.324
22. My thoughts often don't occur as words but as visual images.	.289*	.068
23. I often take delight in small things (like the five-pointed star shape that appears when you cut an apple across the core or the colors in soap bubbles).	.143	.313
24. When listening to organ music or other powerful music I sometimes feel as if I am being lifted into the air.	.297*	.261
25. Sometimes I can change noise into music by the way I listen to it.	.132	.238
26. <i>Some of my most vivid memories are called up by scents and smells.</i>	.099	.232
27. Some music reminds me of pictures or changing color patterns.	.164	.289
28. I often know what someone is going to say before he or she says it.	.416**	.272
29. I often have "physical memories"; for example, after I have been swimming I may still feel as if I am in the water.	.286*	.295
30. The sound of a voice can be so fascinating to me that I can just go on listening to it.	.233	.403
31. At times I somehow feel the presence of someone who is not physically there.	.263*	.398
32. Sometimes thoughts and images come to me without the slightest effort on my part.	.329*	.415
33. I find that different odors have different colors.	.251	.225
34. I can be deeply moved by a sunset.	.237	.445*

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$. $N = 58$ in HSAM vs Control column, & $N = 20$ for 10DQ (= 10 Date Quiz) column. Items (19, 26) involving episodic memory are *italicized*. ¹*Metacognitive*: self-assessment of own memory. Participants indicated the percentage of the time they had the experience (when not under the influence of alcohol or drugs), on a scale from 0% = *never* to 100% = *always*. Largest effect size in column shown in **boldface**.

Table 2. *Fantasy Proneness (Creative Experiences Questionnaire): Each Item's Effect Sizes (r) Indicating How HSAM and Controls Differ and Associations with HSAM ability (10 Date Quiz).*

	HSAM vs Control	HSAM 10 Date Quiz
1. As a child, I thought that the dolls, teddy bears, and stuffed animals that I played with were living creatures.	-.008	-.115
2. As a child, I strongly believed in the existence of dwarfs, elves, and other fairy tale figures.	-.166	.429
3. As a child, I had my own make believe friend or animal.	.248	.222
4. As a child, I could very easily identify with the main character of a story and/or movie.	-.065	.276
5. As a child, I sometimes had the feeling that I was someone else (e.g. a princess, an orphan, etc).	.011	.220
6. As a child, I was encouraged by adults (parents, grandparents, brothers, sisters) to fully indulge myself in my fantasies and daydreams.	-.020	.487*
7. As a child, I often felt lonely.	.228	.147
8. As a child, I devoted my time to playing a musical instrument, dancing, acting, and/or drawing.	.011	-.117
9. I spend more than half the day (daytime) fantasizing or daydreaming.	.170	.145
10. Many of my friends and/or relatives do not know I have such detailed fantasies.	.268*	.525**
11. Many of my fantasies have a realistic intensity.	.341**	.521*
12. Many of my fantasies are often just as lively as a good movie.	.243	.411
13. I often confuse fantasies with real memories.	.089	-.159
14. I am never bored because I start fantasizing when things get boring.	.106	.451*
15. Sometimes I act as if I am somebody else and I completely identify myself with that role.	.077	-.020
16. <i>When I recall my childhood, I have very vivid and lively memories.¹</i>	.290*	NV
17. <i>I can recall many occurrences before the age of three.</i>	-.016	.422
18. When I perceive violence on television, I get so into it that I get really upset.	.132	.298
19. When I think of something cold, I actually get cold.	.015	.057
20. When I imagine I have eaten rotten food, I really get nauseous,	-.044	.241
21. I often have the feeling that I can predict things that are bound to happen in the future.	.302*	.264
22. I often have the experience of thinking of someone and soon afterwards that particular person calls or shows up.	.461***	.241
23. I sometimes feel that I have had an out of body experience.	.062	.087
24. When I sing or write something, I sometimes have the feeling that someone or something outside myself directs me.	.256	.322
25. During my life, I have had intense religious experiences which influenced me in a very strong manner.	.228	.131

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$. $N = 58$ in the HSAM vs Control column, and $N = 20$ for the 10DQ (= 10 Date Quiz) column. Items (16,17) involving autobiographical memory are *italicized*. ¹*Metacognitive question*: self-assessment of own autobiographical memory. NV = no variance. Participants answered "Yes" or "No" to the questions. Largest effect size in column shown in **boldface**.

Testing the Emotional Arousal Hypothesis

Anxiety. Psychic trait anxiety (SSP personality scale subscale) was significantly higher in HSAM individuals ($M = 2.52, SD = .53$) compared to controls ($M = 2.17, SD = .52$), $t(56) = 2.40, p = .020, d = 0.64$. However, somatic trait anxiety did not significantly differ between HSAM individuals ($M = 2.20, SD = .50$) and controls ($M = 2.04, SD = .57$), $t(56) = 1.04, p = .301 (d = .26)$. Neither psychic ($r = .19, p = .42$) nor somatic anxiety ($r = .33, p = .15$) was a significantly associated with 10 Date Quiz scores within the HSAM group.

Empathy. Affective empathy (BES) did not differ significantly between HSAM ($M = 39.15, SD = 8.13$) and control participants ($M = 37.29, SD = 6.25$), $t(56) = 0.97, p = .336, d = .26$. Similarly cognitive empathy was not statistically significantly higher in HSAM individuals ($M = 36.9, SD = 4.40$) compared to control participants ($M = 35.74, SD = 3.76$), $t(56) = 1.05, p = .296, d = .28$.

Emotional Detachment. HSAM participants had significantly lower emotional detachment scores ($M = 2.00, SD = .50$) compared to controls ($M = 2.34, SD = .46$), $t(56) = 2.63, p = .011, d = .70, (r = .332)$.

High Arousal Emotions. On a composite of high arousal emotions (Stressed, Tense, Jumpy), HSAM participants ($M = 4.15, SD = 2.46$) did not report feeling high arousal emotions more often than control participants ($M = 4.03, SD = 2.50$) in the week after 9/11, $t(56) = 0.18, p = .858, d = .05$. Within the HSAM group higher reports of emotional arousal was not significantly associated with scores on the 10 Dates Quiz, $r = .41, p = .070$, although the result was marginal.

Testing the Sleep Hypothesis

Over the seven day observation period cumulative sleep scores were calculated for each participant. All 20 HSAM participants filled in their sleep diaries and returned them, and 35 of the 38 controls did so.

Quantity. On the cumulative amount of sleep over the week, HSAM participants ($M = 2994$ minutes, $SD = 348$) were not statistically different from age matched controls ($M = 3040$, $SD = 303$), $t(53) = 1.19$, $p = .240$, $d = .33$.

Quality. HSAM participants reported feeling well rested in the seven days when they awoke did not differ by a statistically significant difference ($M = 5.10$ days out of seven, $SD = 1.37$) than controls ($M = 4.26$ days, $SD = 1.96$), $t(53) = 1.70$, $p = .096$, $d = .47$, although the result was marginal. Because of this marginal p value the correlation within the 20 HSAM participants between the number of well rested reports and 10 Date Quiz scores was examined, but was not significant ($r = .05$, $p = .573$).

Daytime Naps. HSAM participants ($M = 1.05$ per week, $SD = 1.39$) were not statistically different from controls ($M = 1.20$, $SD = 1.61$) on the number of daytime naps they had during the week, $t(53) = 0.35$, $p = .728$. Likewise, the number of minutes slept during daytime naps did not vary between HSAM individuals ($M = 72.4$ minutes per week, $SD = 117$) and controls ($M = 73.9$, $SD = 104$), $t(53) = 0.05$, $p = .960$.

Multivariate Analysis

Due to the small number of HSAM participants, a multivariate analysis of the possible predictors of the 10 Date Quiz should be viewed with some caution. Nevertheless, a multivariate analysis is shown in Table S1 of the Supplemental Material. To complete this analysis, fantasy proneness was chosen as the strongest associate of the 10 Date Quiz, and absorption was left out of the model due to collinearity with fantasy proneness. The multivariate hierarchical linear

regression shown in Table S1 demonstrates a similar pattern of results in a multivariate analysis to the bivariate findings shown above. Specifically, when statistically adjusting for age, gender, and variables related to emotional arousal and sleep hypotheses, fantasy proneness remained statistically significantly associated with HSAM ability (10 Date Quiz scores). Interestingly, when adjusting for all these variables, high-arousal emotion ratings (for how they felt in the week after 9/11) also was associated with HSAM ability. Other variables within the emotional arousal hypothesis were not significantly associated to 10 Date Quiz scores. These multivariate results, though slightly different than the bivariate results, do reinforce the general finding that the imaginative absorptive hypothesis is most supported, with mixed support for the emotional arousal and sleep hypotheses.

Exploratory Analysis of Other Individual Differences

Handedness. On the Oldfield (1971) 12-item handedness scale, HSAM individuals had an average handedness score of $M = 4.14$ ($SD = 0.84$), corresponding to an overall right-handed preference. Control participants also had a right handed preference on aggregate ($M = 4.20$, $SD = 0.53$). There was no statistical difference on handedness between HSAM and control individuals, $t(56) = 0.29$, $p = .776$, $d = .09$.

SAT scores. There were no significant differences on total SAT scores between HSAM individuals ($M = 1170$, $SD = 182$; $n = 16$) and age match controls ($M = 1241$, $SD = 151$; $n = 18$), $t(32) = 1.23$, $p = .227$, $d = .42$. No statistically differences were found on the SAT Math section between HSAM individuals ($M = 614$, $SD = 84.5$) and controls ($M = 632$, $SD = 95.3$), $t(24) = .51$, $p = .613$, $d = .20$. Similarly on the SAT Reading subsection, HSAM individuals ($M = 578$, $SD = 64.7$) scored statistically no differently from controls ($M = 628$, $SD = 119.8$), $t(25) = 1.37$, $p = .183$, $d = .52$.

Critical Thinking. On the composite of 9 questions testing various aspects of critical thinking, HSAM individuals ($M = 3.55$, $SD = 2.06$) did not score significantly different from controls ($M = 4.24$, $SD = 2.43$), $t(56) = 1.08$, $p = .287$, $d = .31$.

Flexible Thinking. On the total flexible thinking score HSAM individuals ($M = 43.9$, $SD = 4.42$) were significantly lower than controls ($M = 46.9$, $SD = 4.92$), $t(56) = 2.28$, $p = .027$, $d = .61$ ($r = .291$). Of the four subscales that make up the flexible thinking scale, one: “Tolerance for Ambiguity” was significant different between groups. HSAM individuals ($M = 4.15$, $SD = .56$) were significantly lower than controls ($M = 4.76$, $SD = .92$) on Tolerance for Ambiguity, $t(54.8) = 2.84$, $p = .006$, $d = .66$ ($r = .311$).

Beliefs about Memory. Table S2 in the Supplemental Material shows the percentage agreement with a number of statements about how memory works, while Table S4 shows the mean scores on those items with comparisons between HSAM and control participants, and HSAM and memory and cognition experts from SARMAC (members of the Society for Applied Research in Memory and Cognition who also have doctorates). Table S4 demonstrates that on many questions, HSAM and age matched control participants have similar beliefs about how memory works: for example most agree that memory is repressed and that some people have photographic memories. However, HSAM participants tend to disagree more with the statements that memory is unreliable and reconstructed, compared to controls. Table S2 and S3 also shows that there are large differences between HSAM individuals and memory and cognition experts (SARMAC) in their beliefs about memory. There are significant differences between HSAM and SARMAC groups on every question, with effect sizes ranging from Cohen’s $d = 1.11$ to 2.00 . HSAM participants do not reflect the consensus of general skepticism among psychology

researchers about the general reliability of memory and the idea that memory can be repressed (Patihis, Ho, Tingen, Lilienfeld, & Loftus, 2014).

Discussion

By assessing how HSAM individuals differ on individual differences measures, and how these measures vary with HSAM ability, the results demonstrate some support for the imaginative-absorption hypothesis, and weaker evidence for the emotional arousal and sleep hypotheses. Regarding the *imaginative-absorption hypothesis*, absorption and the tendency to fantasy both were reliably higher in HSAM participants compared to controls. This initial result suggested that tendencies to become absorbed into new experiences and to be prone to vividly imaginative episodes, tendencies previously associated with memory errors, could actually have a beneficial effect on one type memory. This suggestion is further supported by the associations shown in Figures 1 and 2 between absorption and fantasy proneness and the measure of HSAM ability, the 10 Dates Quiz. This lends support to hypothesis that certain dispositions may partially explain HSAM.

This raises the question as to how could absorption and fantasy proneness be affecting HSAM. Figure 5 illustrates possible pathways that might explain the relationship.

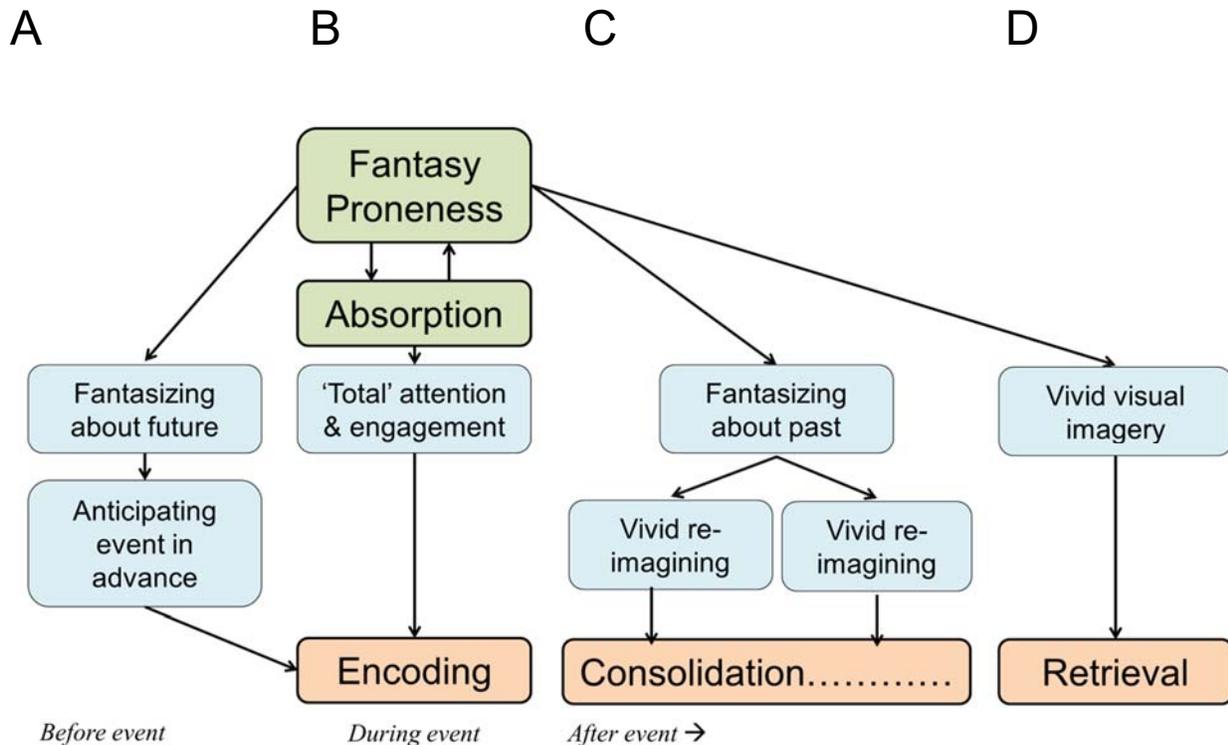


Figure 5. Speculative pathways through which dispositions towards fantasy proneness and absorption could explain HSAM. (A) Before the autobiographical event, a tendency to fantasize about upcoming life events could lead to anticipation that aids encoding at the time of the event. (B) During the event, absorption, the “disposition for having episodes of ‘total’ attention that fully engage” could strengthen encoding of significant life events. (C) After an important event, fantasizing about the event at later dates could bring the event back to mind multiple times, and aid in consolidating a memory. (D) At retrieval, a tendency for strong visual imagery, an aspect of fantasy proneness, could result in memory reports that are rich in detail. Note that these associations may be non-causal, the direction of causality could be bidirectional, or the reverse of that hypothesized.

In Patihis et al. (2013) the finding that HSAM individuals had higher false memories than controls on a misinformation task was mediated by absorption and fantasy proneness. Therefore, the very same tendencies could explain both a deeper attention to misinformation narratives and HSAM. In the absence of misinformation, the personal events in which HSAM individuals become absorbed in and fantasize about later will likely lead to accurate memory. Deep absorption in misleading post-event information, though, can produce errors.

One possible limitation is a potential selection bias: HSAM participants, though matched on age and gender to controls, were not matched on other variables and they might be higher on absorption or fantasy proneness due to something else other than HSAM ability (e.g. profession). All the associations found in this study could be the result of a bidirectional relationship, a causal direction opposite to the one proposed, or due to an unknown third variable. This is also true of individual differences found in previous studies (e.g. structural brain differences and obsessive tendencies in LePort et al., 2012). However, this does not explain the correlations between absorption/fantasizing and HSAM ability within superior memory individuals. HSAM may be a multi-causal phenomenon and indeed other factors are needed to fully explain it. For example, not all highly fantasy prone people have HSAM. It may be that HSAM individuals have a very specific *type* of fantasy proneness that involves fantasizing about real autobiographical events. As well as these dispositions, HSAM development could require the structural brain capacity to remember so many autobiographical details (cf. LePort et al., 2012). These factors may interact in a system. For example, dispositions that drive a person to fantasize about past events could lead to the frequent use of memory systems that result in brain changes over time. Likewise brain systems allowing for rich visual imagination may result in people more prone to fantasize.

Less support was found for the *emotional arousal hypothesis*. Although statistically significant results for psychic trait anxiety and emotional detachment were found, they were not associated with HSAM ability. Empathy and high arousal emotions after 9/11 were not significant correlates with HSAM (by group or within HSAM). These findings do not completely rule out the emotional arousal hypothesis, and further research is warranted, perhaps measuring epinephrine levels directly. However, it appears that emotional arousal may be a lesser

correlate of HSAM than the tendencies to become absorbed in and fantasize about autobiographical events.

The *sleep consolidation hypothesis* was not supported with regards to sleep quantity, but further research may be fruitful in investigating sleep quality. Nevertheless, sleep quality did not show the double associative qualities (group comparison and 10 Date Quiz Scores) of absorption and fantasy proneness variables.

This study identified certain types of dispositions as a speculative but plausible partial explanation of HSAM. The dispositions of absorption and fantasy proneness, specifically if directed towards personal events, have logical theoretical pathways through which they might operate (Figure 5). The finding that these measures are higher in HSAM participants compared to controls is the basis of the argument. This is reinforced by the correlations between these dispositions and HSAM ability (Figures 2 & 4).

In summary, HSAM individuals may have personalities that are related to obsessiveness (LePort et al., 2012), fantasizing about events related to the self, and becoming absorbed in new experiences. Personality is a plausible explanation that helps explain the stable memory-related daily behavior (behaviors such as paying attention or re-imagining events) that would be needed to remember something from everyday decades later. This underlying personality may help HSAM individuals sustain a daily consolidation of a few items of autobiographical memory, such as the date, the day of the week, a news event, and a personal event. In addition, Leport et al. (2012) found brain areas involved in autobiographical memory that differ in size compared to controls could complement this explanation of the HSAM phenomenon. Whether from practice or genetics HSAM individuals might have the neural substrate needed to encode and consolidate

personally meaningful events with more ease than the average person. These correlates, in combination, provide some speculative clues to how HSAM might form.

Author contributions

L. Patihis developed the study concept and study design. Direct recruitment and data collection of the individual differences measures were performed by L. Patihis and research assistants. L. Patihis performed the data analysis and interpretation. L. Patihis wrote the manuscript. The author approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The author declared that he had no conflicts of interest with respect to their authorship or the publication of this article.

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Table S1

Multivariate Hierarchical Linear Regression with 10 Dates Quiz score as the Dependent Measure (within HSAM Individuals; N = 20)

Model	Independent Variables	Unstandardized		Standardized		95.0% CI for <i>b</i>		Correlations			Collinearity		
		Coefficients	SE(<i>b</i>)	β	<i>t</i>	<i>p</i>	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	76.19	4.56		16.70	<.001	66.61	85.78					
	Fantasy Proneness	1.13	.38	.575	2.99	.008	.33	1.92	.58	.58	.58	1.00	1.00
2	(Constant)	82.20	8.00		10.28	<.001	65.25	99.16					
	Fantasy Proneness	1.16	.40	.590	2.87	.011	.30	2.01	.58	.58	.57	.93	1.07
	Age	-.16	.17	-.193	-.95	.355	-.51	.19	-.11	-.23	-.19	.97	1.03
	Gender (0 male, 1 female)	-.85	4.13	-.043	-.21	.839	-9.60	7.89	-.16	-.05	-.04	.97	1.08
3	(Constant)	88.62	28.22		3.14	.011	25.73	151.50					
	Fantasy Proneness	.97	.39	.495	2.48	.032	.10	1.84	.58	.62	.43	.74	1.35
	Age	-.14	.16	-.174	-.93	.377	-.49	.20	-.11	-.28	-.16	.84	1.20
	Gender (0 male, 1 female)	-1.79	5.25	-.090	-.34	.740	-13.48	9.91	-.16	-.11	-.06	.43	2.34
	Empathy (overall)	-.15	.27	-.176	-.54	.599	-.74	.45	.008	-.17	-.09	.28	3.56
	Psychic Trait Anxiety	5.61	3.82	.336	1.47	.173	-2.91	14.12	.19	.42	.25	.56	1.77
	Detachment	2.79	5.06	.156	.55	.594	-8.48	14.06	.06	.17	.10	.37	2.72
	High Arousal Emotion (911)	1.71	.67	.472	2.54	.029	.21	3.12	.41	.63	.44	.86	1.17
Sleep Quantity (wk average)	-.01	.01	-.494	-1.95	.080	-.03	.002	-.19	-.53	-.34	.46	2.17	
	Sleep Quality (Felt Rested)	3.22	1.90	.498	1.69	.121	-1.02	7.46	.05	.47	.29	.34	2.94

Model Summary Statistics

Model	<i>R</i>	<i>R</i> ²	Adjusted <i>R</i> ²	SE of the Estimate	Change Statistics					Durbin-Watson
					<i>R</i> ² Change	<i>F</i> Change	<i>df</i> 1	<i>df</i> 2	<i>F</i> Change <i>p</i> value	
1	.58	.33	.29	7.45	.33	8.91	1	18	.008	
2	.61	.37	.25	7.69	.04	0.46	2	16	.640	
3	.84	.70	.44	6.65	.34	1.90	6	10	.176	2.14

Note. Statistically significant correlates of 10 Date Quiz scores are bolded.

Table S2

Percentage of Participants Agreeing to Some Degree^a with Various Statements about Memory and Repression

Participant Group	Traumatic memories are often repressed.	Repressed memories can be retrieved in therapy accurately.	Memory can be unreliable.	Hypnosis can accurately retrieve memories that previously were not known to the person.	Memory is constantly being reconstructed and changed every time we remember something.	Memory of everything experienced is stored permanently in brains, even if can't access all.	Some people have true "photographic memories."	With effort, we can remember events back to birth.
HSAM (<i>n</i> = 20)	85.0	85.0	60.0	55.0	65.0	85.0	90.0	20.0
Control (age, sex matched; <i>n</i> = 38)	73.7	71.1	89.5	50.0	92.1	63.2	86.8	31.6
SARMAC (PhD; <i>n</i> = 51)	23.5	15.7	98.0	11.8	98.0	25.5	29.4	2.0

Note. Likert scale had the following 6 anchors: *strongly disagree*, *disagree*, *slightly disagree*, *slightly agree*, *agree*, and *strongly agree*. ^aAgreeing to some degree means participants chose *slightly agree*, *agree*, or *strongly agree* to the statements. SARMAC = Society for Applied Research in Memory and Cognition who are also doctorate (PhD) holders. SARMAC data are from same dataset as Patihis *et al.* (2014), after removing those without doctorates.

Table S3

Comparing HSAM Individuals' Beliefs about Memory to Experts in Memory and Cognition: M, (SD), and n given for comparisons.

Participant group	<i>n</i>	(1) ^a Recovered CSA Plausible	(2) ^b Traumatic memories are often repressed	(3) Repressed memories can be retrieved in therapy	(4) Memory can be unreliable	(5) Hypnosis accurately retrieves memories	(6) Memory is reconstructed	(7) Memory of everything is stored	(8) Photographic memories	(9) Can remember back to birth
HSAM	20	2.75 (0.639)	4.50 (0.946)	4.00 (1.124)	3.60 (1.465)	3.35 (1.182)	3.70 (1.174)	4.50 (1.192)	5.00 (1.376)	2.55 (1.099)
Age sex-matched Control	38	2.74 (0.724)	4.03 (1.150)	3.79 (1.119)	4.95 (1.138)	3.55 (1.155)	4.68 (0.933)	3.76 (1.478)	4.71 (1.250)	2.68 (1.435)
<i>t</i> test between HSAM and Control		<i>t</i> (56) = 0.07 <i>p</i> = .946 <i>d</i> = .01	<i>t</i> (56) = 1.58 <i>p</i> = .120 <i>d</i> = .45	<i>t</i> (56) = 0.68 <i>p</i> = .499 <i>d</i> = .19	<i>t</i>(56) = 3.88 <i>p</i> < .001 <i>d</i> = 1.03	<i>t</i> (56) = 0.63 <i>p</i> = .531 <i>d</i> = .17	<i>t</i>(56) = 3.49 <i>p</i> = .001 <i>d</i> = .92	<i>t</i> (56) = 1.92 <i>p</i> = .060 <i>d</i> = .55	<i>t</i> (56) = 0.81 <i>p</i> = .289 <i>d</i> = .22	<i>t</i> (56) = 0.37 <i>p</i> = .716 <i>d</i> = .10
Experts Memory & Cogn. (SARMAC; PhD)	51	2.02 (0.678)	2.18 (1.396)	1.94 (1.139)	5.80 (0.530)	1.88 (0.993)	5.55 (0.673)	2.28 (1.429)	2.65 (1.547)	1.20 (0.566)
<i>t</i> test between HSAM and SARMAC		<i>t</i>(69) = 4.09 <i>p</i> < .001 <i>d</i> = 1.11	<i>t</i>(69) = 6.83 <i>p</i> < .001 <i>d</i> = 1.95	<i>t</i>(69) = 6.88 <i>p</i> < .001 <i>d</i> = 1.82	<i>t</i>(69) = 9.35 <i>p</i> < .001 <i>d</i> = 2.00	<i>t</i>(69) = 5.31 <i>p</i> < .001 <i>d</i> = 1.35	<i>t</i>(69) = 8.33 <i>p</i> < .001 <i>d</i> = 1.93	<i>t</i>(69) = 6.15 <i>p</i> < .001 <i>d</i> = 1.69	<i>t</i>(69) = 5.93 <i>p</i> < .001 <i>d</i> = 1.61	<i>t</i>(69) = 6.81 <i>p</i> < .001 <i>d</i> = 1.54

Note. Significant differences highlighted in **boldface**. Mean ratings given with standard deviations in parenthesis. ^aQuestion (1) Likert scale: 1 = *very implausible*; 2 = *implausible*; 3 = *plausible*; 4 = *very plausible*. ^bQuestions (2) through (9) Likert scale: 1 = *strongly disagree*; 2 = *disagree*; 3 = *slightly disagree*; 4 = *slightly agree*; 5 = *agree*; 6 = *disagree*. SARMAC = Society for Applied Research in Memory and Cognition who also have a PhD.

Critical Thinking Scale

(from West, Toplak, & Stanovich, 2009; but also see Kirkpatrick & Epstein, 1992; Levesque, 1986, 1989; Tversky & Kahneman, 1974; Stanovich, 2009)

Directions: Please read the following questions carefully and choose the best answer.

1. It is known that 1 dollar out of every 10,000 is counterfeit. Imagine a money-changing machine that rejects real dollar bills 5 out of every 100 times it changes money. However, it always rejects bills when they are counterfeit. If this machine rejects your dollar bill, what is the probability (expressed as a percentage ranging from 0% to 100%) that your bill is counterfeit? Choose the best answer.

- (a) Less than 1%
- (b) About 5%
- (c) About 50%
- (d) About 95%
- (e) More than 95%

2. When playing slot machines, people win something about 1 in every 10 times. Lori, however, has just won on her first three plays. What are her chances of winning the next time she plays? Choose the best answer.

- (a) She has better than 1 chance in 10 of winning on her next play
- (b) She has less than 1 chance in 10 of winning on her next play
- (c) She has a 1 chance in 10 that she will win on her next play.

3. A doctor had been working on a cure for a mysterious disease. Finally, he created a drug that he thought would cure people of the disease. Before he could begin to use it regularly, he had to test the drug. He selected 400 people at random who had the disease. Of the 400, he randomly assigned 300 to the treatment group and gave them the drug to see what happened. He randomly assigned 100 people to the no-treatment group and gave them a placebo (a sugar pill manufactured to look like the treatment drug) to see what happened. Table 1 below indicates the outcome:

Drug condition	Group	
	Cured	Not cured
Received	200	100
Did not receive	75	25

Table 1.

Choose the statement that best summarized the results shown in the table from among the following statements:

- (a) The evidence indicates that the drug was effective
- (b) The evidence is inconclusive
- (c) The evidence indicates that the drug was not effective

4. Assume that you are presented with two trays of black and white marbles: a large tray that contains 100 marbles and a small tray that contains 10 marbles. The marbles are spread in a single layer on each tray. You must draw out 1 marble (without peeking, of course) from either tray. If you draw a black marble, you win \$2.

Consider a condition in which the small tray contains 1 black marble and 9 white marbles, and the large tray contains 8 black marbles and 92 white marbles.

From which tray would you prefer to select a marble in a real situation?

- (a) small tray
- (b) large tray

5. There are 3 blocks in a stack, where each of the blocks is either new or old. The top block is new, and the bottom one is old. The middle block is either new or old. Is there a new block directly on top of an old block?

- (a) Yes,
- (b) No
- (c) Cannot be determined.

6. A certain town is served by two hospitals. In the larger hospital, about 45 babies are born each day, and in the smaller hospital, about 15 babies are born each day. As you know, about 50 percent of all babies are boys. However, the exact percentage varies from day to day. Sometimes it is higher than 50 percent, sometimes lower. For a period of one year, each hospital recorded the days on which more than 60 percent of the babies born were boys. Which hospital do you think recorded more such days?

- (a) The larger hospital
- (b) The smaller hospital
- (c) About the same

16. Imagine an urn filled with balls, two-thirds of which are of one color and one-third of which are of another. Tom has drawn 5 balls from the urn and found that 4 are red and 1 is white. Ben has drawn 20 balls and found that 12 are red and 8 are white. Which of the two individuals should feel more confident that the urn contains two-thirds red balls and one-third white balls, rather than vice versa?

- (a) Tom
- (b) Ben

17. Jack is looking at Anne but Anne is looking at George. Jack is married but George is not. Is a married person looking at an unmarried person?

- (a) Yes
- (b) No
- (c) Cannot be determined

18. A bat and ball cost \$1.10 in total. The bat costs \$1 more than the ball. How much does the ball cost?

_____ cents

Supplemental References

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