SUBJECTIVE TIME PERCEPTION PREDICTS DELAY OF GRATIFICATION

By

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Abstract

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This study investigated the relationship between time perception and impulsivity using a healthy, undergraduate population. The 79 participants were Introductory Psychology students at a Midwestern University. Data were collected on internal clock speed (ICS), behavioral impulsivity, intelligence, and several personality measures. As expected, ICS predicted behavioral impulsivity beyond known predictors of impulsivity (R^2=.073, B= -11.05, p=.022). When using multiple regression analyses, ICS and known predictors accounted for 24.9% (F[4,61]=4.72, p=.002) of the variance. However, unexpectedly, participants who had slower ICS were more impulsive than participants who had faster ICS (r=-.311, p=.014). A predictive model combining ICS error and known predictors accounted for 26.5% (F[4,61]=5.14, p=.001) of the variance in behavioral impulsivity. As anticipated, participants who had more error in ICS were more impulsive than participants who had less error (r=.428, p=.001). Results are discussed in terms of current theory relating ICS and impulsivity, and a new theoretical framework is advanced.

Introduction

The ability to delay gratification has important consequences in everyday life. Choosing not to eat a cookie in favor of better long-term health, or saving money in a retirement plan require the ability to delay gratification, and this ability has been linked to future success. People who are able to delay gratification are often found to be more cognitively, emotionally and socially competent than those who fail to delay gratification. Additionally, those who are able to delay gratification typically handle stress better and have better interpersonal relationships than those who are unable to do so (Ayduk, Mendoza-Denton, Mischel, Downey, Peake, et al., 2000; Loewenstein, Read & Baumeister, 2003; Peake, Hebl & Mischel, 2002).

The ability to delay gratification is associated with a couple of related terms which will be used in this paper. "Delay of gratification" is conversely related to both "impulsivity" and "delay discounting". For example, someone who is often able to delay gratification would be considered less impulsive than some who rarely delays gratification. Delay discounting refers to the degree to which an individual devalues rewards expected at a future time (Hirsh, Morisano & Peterson, 2008; Wittmann and Paulus, 2007). For example, compared to a relatively non-impulsive individual, a highly impulsive person would discount future rewards more (i.e., s/he would consider a future reward as less valuable).

Delay of gratification ability can be observed early in life. In their research, Mischel and Underwood (1974) used delay discounting tasks to measure children's abilities to delay gratification. They found that even some preschool and primary school children (ages 3-8) delay gratification to receive greater rewards. The children in their study were given one marshmallow and asked to wait in a room for a researcher to return. The children knew that if after the researcher returned, and they had not eaten the marshmallow, they would be given a second marshmallow. However, if the marshmallow was eaten before the researcher returned (20 minutes later), the children would not get a second marshmallow. Some children were more impulsive than others. The less impulsive children waited 20 minutes until the researcher returned and received two marshmallows, whereas the more impulsive children were not able to wait (Mischel & Underwood, 1974). The less impulsive children either did not discount the two marshmallows as much because of the 20 minute delay, or they were unable to develop a strategy to help them to delay gratification.

Delay of gratification abilities tend to remain stable over time. Mischel, Shoda and Peak (1988) tested four and five year olds with delay discounting tasks. These tasks were variations of the marshmallow task described above, but with alternate rewards and different instructions regarding the wait times. Ten years later, the participants' parents were asked to provide information regarding their children's academic and social successes. Remember, those with better delay of gratification abilities tend to be more cognitively, emotionally and socially competent than those who fail to delay gratification (Ayduk, Mendoza-Denton, Mischel, Downey, Peake, et al., 2000; Loewenstein, Read & Baumeister, 2003; Peake, Hebl & Mischel, 2002). Results revealed that those participants who delayed longer as preschoolers were rated as more socially competent, academically competent, attentive, and able to handle stress better than those participants who were not able to delay as long when in preschool. Those participants who had better delay of gratification abilities as preschoolers tended to plan for the future more often than those who could not delay gratification as well; and in this study, being more planful was used as an indicator of delay of gratification abilities (Mischel, Shoda, & Peake, 1988). These results indicate that delay of gratification abilities tend to remain stable over time.

Predictors of Delay of Gratification

One factor highly associated with the ability to delay gratification is intelligence. Shamosh and Gray (2008) conducted a meta-analysis using 24 studies which showed a negative relationship between intelligence and impulsivity. That is, participants with higher intelligence were typically willing to wait longer to receive a more desirable reward (ex: $25 dollars in ten weeks rather than $20 today) than those with lower intelligence.

When looking at the relationship between working memory and impulsivity, working memory has been found to explain no more variance than intelligence alone (Shamosh, DeYoung, Green, Reis, Johnson, et al., 2008). In this study, Shamosh et al. (2008) asked participants to complete two computerized working memory tasks (Operation span and N-Back), two intelligence tasks (Raven's Advanced Progressive Matrices, set II and the Culture Fair Intelligence Test), and several hypothetical delay discounting questions (i.e., "Would you rather receive $10 immediately or $200 in one year from now?"). Both working memory and intelligence significantly correlated with delay discounting, but working memory alone did not predict delay discounting above and beyond intelligence (Shamosh, DeYoung, Green, Reis, Johnson, et al., 2008).

Along with intelligence, self-reported impulsivity is another predictor of behavioral impulsivity. Those who report difficulty in delaying gratification tend to behaviorally respond as such (Wit, Flory, Acheson, McCloskey & Manuck, 2007; Wittmann, Leland, Churan & Paulus, 2007; Berlin & Rolls, 2004). Borderline Personality Disorder (BPD) patients are characterized as being behaviorally impulsive, and have been a group of interest when studying impulsivity (e.g., Berlin & Rolls, 2004). Berlin and Rolls (2004) examined both self-reported and behavioral impulsivity in persons with BPD and healthy controls. Participants completed the Barratt Impulsiveness Scale, version II (Patton et al., 1995), which is a measure of self-reported impulsivity. They also performed the computerized Matching Familiar Figures Test, which is a measure of behavioral impulsivity. Berlin and Rolls (2004) found that the BPD patients were more impulsive than controls both in terms of their self-reported impulsivity and in terms of their behavioral impulsivity, and that a positive correlation existed between self-reported and behavioral impulsivity. In a different study, Wit et al. (2007) tested healthy, middle-aged adults on both self-reported and behavioral impulsivity. The researchers used the Barratt Impulsivity Scale, Version 10-RIS (BIS 10-R, Barratt, 1985) as a measure of self-reported impulsivity, as well as a variety of delay discounting questions (i.e., "Would you prefer $10 today or $50 in 90 days from now") to measure behavioral impulsivity. Results showed significant positive correlations between the self-reported BIS scores and decision-making via the delay discounting measures. Specifically, participants with higher self-reported impulsivity tended to make more impulsive decisions (Wit et al, 2007).

Gender is another factor that may play a role in impulsivity. Silverman (2003) found a small relationship between gender and intelligence from his 33-study meta-analysis. Silverman (2003) determined that women behaved slightly less impulsively than men through analyses of effect sizes of gender difference ($r = .058$, $p = .05$). However, these results were dependent upon the type of delay discounting measure used. When conducting his meta-analysis, Silverman (2003) noticed that not all of his studies were equivalent with regard to how delay discounting was measured. Therefore, he split the 33 studies into two different groups - those with continuous measures and those with dichotomous measures. Silverman found that significant effect sizes of gender differences only existed when continuous measures were used ($r = .096$, $p < .001$). He also reported that gender differences did not appear as a function of age for either dichotomous or continuous measures of delay discounting. While Silverman (2003) meta-analytically uncovered slight gender differences, many researchers have found no differences in impulsivity between men and women in their individual studies (e.g., Funder & Block, 1989; Kirby & Marakovic, 1995; Mischel & Metzner, 1962; Mischel & Mischel, 1983; Wit, Flory, Acheson, McCloskey & Manuck, 2007).

An additional predictor of impulsivity may be one's perception of time, how fast or slow one senses the passage of time. Objective time is subjectively experienced differently by different people. What feels like 10 minutes to one person may feel like 15 minutes to someone else. For example, two people can wait in the same grocery line for the same amount of time. For one of those two people the wait time may actually feel like 10 minutes, however, for the second person those exact same 10 minutes might feel like 15 minutes. Recognizing that people can experience the same objective time differently may help researchers better understand impulsivity. For example, a person may value a reward differently than someone else because of the amount of time he or she would subjectively have to wait before receiving that reward (Wittmann & Paulus, 2008). When measuring impulsivity, a frequently used task requires participants to think about the amount of money they would need, at some specified future time, in order to forgo receiving a smaller amount today (Reynolds, Ortengren, Richards & Wit, 2005). Typically, the longer the delay the less valued the reward (Mischel & Metzner, 1962). However, one's *perception* of the specified delay may significantly impact if, and for how long, one is willing to wait for a reward. For example, if someone were asked to wait 10 weeks prior to receiving a reward, based on his or her subjective time, those 10 weeks may feel like only 8 weeks or possibly even 12 weeks. Remember, personal subjective time is how fast or slow one *senses* time to be passing; it is not the actual, objective time. According to Wittmann and Paulus (2008), impulsive decisions may be made because of an overestimation of time. Overestimation of time occurs when one has a fast subjective sense of time (a fast "internal clock"); one's subjective time is passing by faster than objective time. To someone with a fast subjective sense of time, those 10 weeks would actually *feel* like 12 weeks, therefore causing the *over*estimation of objective time. As a result, one may respond impulsively (forgo the larger, delayed reward) because of the long wait they would subjectively have to experience.

The subjective experience of time is dependent on one's "internal clock speed" (ICS). People with fast and slow ICS count time more quickly and slowly, respectively, relative to objective time. For example, someone with a fast ICS might say 45 seconds have elapsed during a 30 second period, but during that same time someone with a slow ICS might report only 20 seconds passing. Wittmann and Paulus (2008) argue that those with faster ICS respond more impulsively than people with slower ICS, because fast ICS causes the delay prior to receiving a reward feel longer than the actual, objective time period. He or she then discounts the reward more because of the prolonged delay, and therefore, acts impulsively by choosing the smaller, but more immediate reward.

ICS can be broken down into three ranges: the millisecond range, the seconds to minutes range, and the long term range (Hinton & Meck, 1997). Millisecond timing is often automatic and used when producing coordinated movements, like picking up a coffee mug, speech production, and stimulus recognition (Buhusi & Meck, 2005). Timing in the seconds to minutes range requires more cognitive processes and is used in tasks such as arithmetic and decision making (Ivery & Spencer, 2004). This is the time range studied when investigating the relationship between ICS and impulsivity. Long term timing encompasses circadian rhythm and seasonal timing which impact sleep-wake cycles, appetite, and other processes (Buhusi & Meck, 2005).

To better understand these ranges, especially the seconds to minutes range, researchers have developed cognitive models, one of which is the information-processing model (Treisman, 1963). In this model, the time keeping component is comprised of a pacemaker, a gate, and an accumulator. The pacemaker produces pulses, which may be faster or slower than one pulse per second. The pulses go through a gate and enter the accumulator in a linear fashion. Once in the accumulator, the pulses are added over time. When required, the number of pulses stored in the accumulator is compared to a value maintained in the reference memory system. The reference memory system includes a sample of the expected time (typically from past experiences). A comparison between the accumulated time and the reference memory time is conducted, and a decision is made regarding the similarity or dissimilarity in the two values (Meck, 1996). This model helps to explain why ICS may be associated with delay of gratification abilities.

Someone with a fast ICS would accumulate pulses at a rate faster than one pulse per second. When given a specified time period to wait, his or her accumulated pulses would be greater than the sample time stored in the reference memory system. After comparing the two times, and seeing his or her pulses out numbering the reference time, he or she would decide that s/he has waited "long enough." As a result, s/he would make the impulsive decision.

There are a variety of ways to measure one's ICS in the seconds to minutes range (Zakay & Block, 1997). Two common techniques used in research studies are time *estimation* and time *production*. When *estimating* time, participants perceive a stimulus for an unknown duration and, once it ends, are required to estimate the length of the duration. For example, participants may be asked to attend to an 'X' in the center of a computer screen. Once the 'X' disappears from the screen, they are prompted to estimate the length of time for which the 'X' appeared on the screen. In time *production* tasks, participants are asked to demarcate a period of time which they feel is equal to a specified time duration. For example, a participant may be asked to produce 60 seconds by holding down a computer key for what he or she feels is 60 seconds. Time estimation and time production are inversely related. For example, someone with a fast ICS would tend to *overestimate* the time period for which the 'X' was present, and would also tend to *underproduce* the 60 seconds. Likewise, someone with a slow ICS would tend to *underestimate* the period of the time that the 'X' was present, and would *overproduce* what he or she felt was 60 seconds.

Researchers studying specialized populations have used these ICS measures to better understand the relationship between time perception and impulsivity within their populations, and perhaps in general. For example, Cappella, Gentile and Juliano (1977) studied hyperactive children. Hyperactive children, and those diagnosed with Attention Deficient Hyper Activity Disorder (ADHD), are characterized as having limited behavioral inhibition, poor attention, hyperactivity and limited ability to delay gratification (Barkley, Murphy, & Bush, 2001). The researchers found that when compared to a control group, hyperactive children overestimated time, implying a slow ICS (Cappella, Gentile, & Juliano, 1977). Meaux and Chelonis (2003), who also studied children with ADHD, found that when compared to a control group, their ADHD participants exhibited more absolute errors for both time production and time estimation tasks; indicating that *accuracy* in time perception is perhaps an important factor impacting impulsivity. Accuracy in time perception and ICS has been studied in the ADHD population, and the results are mixed as to the relationship between impulsivity and time perception (see Table 1 for a summary of results). Regardless of whether researchers believe a fast ICS, a slow ICS, or accuracy is the main factor impacting impulsivity, most agree that children and adults with ADHD have impaired time perception, and this impairment may be related to the impulsive behaviors these patients exhibit (Barkley et al., 1997; 2001; Meaux & Chelonis, 2003; Toplak et al., 2003).

Another special population associated with impaired time perception includes patients with Borderline Personality Disorder (BPD). These patients exhibit behavioral impulsivity such as drug use/abuse, excessive spending/ gambling, sexual promiscuity, self-injurious behavior, etc. Impulsivity is a core characteristic for diagnosis of BPD (Berlin & Rolls, 2004). Berlin and Rolls (2004; 2005) investigated the relationship between impulsivity, time perception, and personality, among other factors in BPD patients. They found that BPD patients consistently underproduced time and trended toward overestimating time when compared with control participants, indicating they may have a fast ICS (Berlin & Rolls, 2004; 2005). Additionally, Berlin and Rolls (2004) found that BPD patients were more impulsive than controls for both self-reported impulsivity and behavioral impulsivity, as measured by the Matching Familiar Figures Test (Kagan, 1966). However, despite underproducing, BPD patients produced time intervals that were closer to the actual time than controls (Berlin & Rolls, 2004). Again, research has been conducted with specialized populations to better understand the relationship between time perception and impulsivity. However, the results are mixed; some report that slow ICS is associated with impulsivity whereas others report fast ICS is associated with impulsivity. Still others argue accuracy in time perception, regardless of clock speed, is the factor which best predicts impulsivity (see Table 1). At present there is still a need for further investigation regarding time perception and impulsivity within a normal population.

Wittmann and Paulus (2008) also expressed a need for future studies that include both measures of time perception and impulsivity in healthy individuals. Therefore, I chose to investigate the relationship between time perception and impulsivity using a healthy population. The methods to be implemented measure time estimation, time production, both self-reported and behavioral impulsivity, as well as personality and IQ factors. It is hypothesized that time perception will predict impulsivity above and beyond known factors (IQ, gender and self-reported impulsivity). Specifically, those who have a faster ICS are expected to behave more impulsively, while those participants who have a slower ICS will behave less impulsively. People with less accurate ICS are expected to be more impulsive relative to people with more accurate ICS. It is hypothesized that men will behave slightly more impulsively than women, and people with lower intelligence will be more impulsive than people with higher intelligence.

The investigation of time perception and impulsivity in a healthy population is an important contribution of this research. Research with a healthy population has only been reported once before by Barratt (1983), but he did not report the methods used in his study. Therefore, this research will not only provide a better understanding between impulsivity and time perception in healthy individuals, but it will also help improve our understanding of how current ICS assessment techniques work when testing healthy participants. Another benefit of this research is that it may help to identify new variables which predict impulsivity level. Finally, this research will contribute to field's previous knowledge about delay of gratification, gender and intelligence.

Method

Participants

All participants were recruited from an undergraduate Introduction to Psychology course at a Midwestern University. A total of 79 participants, 28 females and 51 males, completed the study. Participants ranged in age from 18-25 years old (M= 19.44, SD=1.35).

Materials

Participants completed paper and pencil questionnaires which included: an in-house demographic questionnaire, the Behavioral Inhibition and Behavioral Activation Scales (BIS/BAS; Carver & White, 1994), the Barratt Impulsivity Scale (BIS-11; Patton et al., 1995), the Big Five Inventory – version 54 (John & Srivastava, 1999), and the Mill

Hill Vocabulary Scales – Senior Form 2: Sets A and B (Raven, Raven, & Court, 1998). Participants also completed three computerized tasks. Two of the tasks, both produced by the Neurobehavioral Research Laboratory and Clinic, included the Time Paradigm v 1.0 (Dougherty, Mathias & Marsh, 2003) and the Two Choice Impulsivity Paradigm (Dougherty, Marsh, & Mathias, 2003). The third computerized task, the Time Estimation task, was created in-house using Microsoft Power Point. Results were analyzed using the Statistical Package for the Social Sciences, version 17.0.

Design

A within-subjects design was utilized, and each participant completed all paper and pencil measures as well as all computerized measures.

Procedures

Participants began the study by completing a variety of paper and pencil tests, which collected basic demographic information, intelligence scores and self-reported impulsivity data. The Behavioral Inhibition and Behavioral Activation Scales (BIS/BAS; Carver & White, 1994), which assess the degree to which people respond to rewards (BAS) and punishments (BIS), were used. Questions within the BIS/BAS include "I'm always willing to try something new if I think it will be fun" (BAS), and "Criticism or scolding hurts me quite a bit" (BIS). Participants responded to 20 questions using a four point likert scale ranging from "strongly agree" to "strongly disagree." The participants' responses were used to score BIS, BAS total, and three additional BAS subscales: BAS Reward Responsiveness, BAS Drive and BAS Fun Seeking. Each subscale includes, on average, five questions. The BAS Reward Responsiveness scale includes items that focus on positive responses related to the anticipation of a reward, for example, "When

I'm doing well at something, I love to keep at it." The BAS Drive scale is made up of items pertaining to pursuing a goal. A sample question for this scale is "When I want something, I usually go all-out to get it." The BAS Fun Seeking scale has items which reflect a desire for new rewards along with a willingness to participate in events on the spur of the moment, e.g., "I'm always willing to try something new if I think it will be fun." The internal consistency coefficients were reported for each subscale: BIS α=.74, BAS Reward Responsiveness α=.73, BAS Drive α=.76, and BAS Fun Seeking α=.66, and all three BAS subscales loaded onto one BAS total factor (.75) within a factor analysis (Carver & White, 1994). The Barratt Impulsivity Scale (BIS-11; Patton, Sanford & Barratt, 1995), which measures self-reported impulsivity, was also administered. This scale includes 30 questions which participants answer on a four point likert scale ranging from "Rarely/Never" to "Always/Almost Always." The Barratt Impulsivity scale also has three subscales which have, on average, nine questions each: Attentional Impulsiveness, Motor Impulsiveness, and Non-Planning Impulsiveness. "I have racing thoughts" and "I don't pay attention" are example of questions which comprise the Attentional Impulsivity scale. The Motor Impulsiveness sub scale includes such questions, "I buy things on impulse" and "I change residences." Finally, the Non-Planning scale incorporates these questions, among others, "I plan trips well ahead of time" and "I plan for job security." The Barratt Impulsivity scale has an internal consistency coefficient of α=.82 (Patton, Sanford, & Barratt, 1995). Participants then completed the Big Five Inventory – version 54 (John & Srivastava, 1999), which is a commonly-used measure of 5 different personality traits: extraversion, agreeableness, conscientiousness, neuroticism, and openness. The Big Five includes 44 questions which are answered according to a 5 point likert scale ranging from "Disagree Strongly" to "Agree Strongly." A variety of questions are scored to assess one's degree of extraversion, agreeableness, conscientiousness, neuroticism and openness, and each subscale has on average eight questions each. Sample questions include "I am someone who is…reserved, tends to be moody, tends to find fault with others, is inventive, is talkative, and is full of energy." The alpha reliabilities of the Big Five Scales range from .75 to .90 (John & Srivastava, 1999). To assess intelligence, participants were asked to complete the Mill Hill Vocabulary Scales (MHVS) Senior Form 2: Sets A and B (Raven, Raven, & Court, 1998). The Mill Hill includes 66 multiple choice vocabulary questions, with each question containing six possible answers. A sample vocabulary word is "Liberty," and the possible answers include "freedom, rich, forest, worry, serviette and cheerful." Participants are scored on the total number of correct answers they provide.

Upon completion of the questionnaires, participants were asked to perform two tasks which measured ICS. The first task, an in-house creation, asked participants to estimate how long an 'X' was present on a computer screen. Once the 'X' disappeared from the screen, participants wrote their estimate on a piece of paper. Unbeknownst to participants, the 'X' was presented for 75 seconds. The task was repeated three times. The second of the time perception tasks measured time production. Participants were asked to hold a computer button down for 60 seconds (Dougherty, Mathias, & Marsh, 2003). Again, participants completed this task three times.

The final task participants completed is called the "Two-Choice Impulsivity Paradigm" (Dougherty, Marsh, & Mathias, 2003), which is a measure of behavioral impulsivity. The objective of this task was to earn as many points as possible because each point earned translated into one penny. Participants were informed they would receive payment, in cash, immediately following the experiment. This task required participants to select one of two different icons on a computer screen. One icon was associated with a real-time 5 second wait to receive 5 cents, and the other was associated with a real-time 15-second wait to receive 15 cents. Participants were not aware of the exact length of time they were required to wait, but they did know that one icon was worth 5 cents and the other was worth 15 cents. Specifically, a participant knew that if s/he chose the circle icon s/he would receive 5 cents and if s/he chose the square icon s/he would receive 15 cents. S/he was not informed that by choosing the circle s/he would have to wait 5 seconds before making another decision, or that by choosing the square s/he would have to wait 15 seconds before making another decision. After receiving instructions on how to perform the task, participants completed 10 “training” choices followed by 50 “real” choices. In the training session, participants learned that one icon was always associated with a 5 cent reward and a shorter wait time, and the second icon was always associated with a 15 cent reward and a longer wait. Again, participants were never explicitly told the exact length of time associated with each icon. Upon completion of the 50 real choices, participants were immediately paid in real money totaling the number of cents/points earned from the 50 real choices. Thus, participants were paid an amount ranging from $2.50 (if s/he selected all 50 5-second/5-cent choices) to $7.50 (if s/he selected all 50 15-second/15-cent choices). This particular task was “real life” in that it required participants to completely experience the rewards and consequences of making impulsive or non-impulsive decisions.

Results

Data were collected from 79 participants (28 females and 51 males) with a mean age of 19.44 (SD=1.35, range: 18-25). However, data from those participants whose native language was not English (N=16), and one subject who did not complete all tasks (N=1) were not included in analyses. As a result, analyses were conducted with an N=62.

Outliers

All variables were assessed for outliers. An outlier was defined as more than three and a half standard deviations above or below the mean. Only one outlier was found, and it was within the average time estimation variable. Specifically, one participant had an extremely high time estimation average. Rather than eliminating the data point or removing the participant completely, his/her average time estimation data was replaced with the value exactly equal to three and a half standard deviations above the mean.

Missing Data

A total of three separate time production variables were recorded for each participant. Three participants had one missing time production data point each. Again, rather than eliminating all three participants from analyses, modifications to their data were conducted. The Cronbach's Alpha was first computed for the time production variable to ensure a high level of internal consistency between the three time production measures; indeed, one was found (α=.925). Cronbach's Alpha was also determined for time estimation. It, too, had a high level of internal consistency (α=.944). Based on the time production α, it was acceptable to take the average of the two existing time production data points to determine the overall time production average for those three participants. All other participants had three data points which were used to determine an overall time production average.

Calculation of Variables

A list of the variables measured and analyzed for each participant can be found in Table 2. Within this table, average time estimation and average time production are listed. Average time estimation was calculated for each participant by simply averaging the three time estimation trials recorded for that particular participant. Average time production was calculated the same way for each participant, except for the three participants mentioned above.

The variable ICS was calculated by taking the average time production (Tp) and average time estimation (Te) for each participant, and determining the percent difference from objective time. The objective time for time production was 60 seconds, and the objective time for time estimation was 75 seconds. ICS was calculated using the following equation: [(60-Tp/60)+(Te-75/75)]/2. If a participant had, for example, an average time production of 57.67 seconds and an average time estimation of 61.33 seconds his or her ICS would be -.07 (i.e., 7% slower than objective time). Please note that positive and negative numbers reflect fast and slow ICS, respectively.

"Total error" was calculated in a similar manner. However, the absolute value of the difference between objective and subjective time was used instead: [(abs(60-Tp)/60)+(abs(Te-75)/75)]/2. A participant with an average time production of 57.67 seconds and average time estimation of 61.33 seconds would report a total error of .11 (11% error in accuracy).

After all variables were defined, a factor analysis was then conducted on the three trials of time production and the three trials of time estimation to assess their underlying structures, see Table 3. The first factor extracted, which accounts for 72.91% of the variance, closely reflects ICS. Time estimation and time production are inversely related, and therefore, as expected, the three time estimation trials positively loaded onto ICS, whereas the three time production trials negatively loaded onto ICS. The second factor, which accounts for 17.43% of the variance, is unknown at this time.

Gender Differences

Gender differences within measured variables were tested. The influence of participant sex on behavioral impulsivity was analyzed using an independent t-test. The results trended towards significance, t(60)=-1.99, p=.051. However, the direction of the relationship ran counter to expectations. Specifically, women (M=12.51, SD=13.38) behaved slightly more impulsively than men (M=6.54, SD=9.98).

Significant gender differences were also seen in the Behavioral Inhibition scale, (t[60]=-.317, p=.002), and the Behavioral Activation total scale (t[60]=2.14, p=.036). Women (M=20.20, SD=3.33) scored significantly higher than men (M=17.46, SD=3.25) on BIS, and women (M=37.17, SD=6.23) scored significantly lower on BAS than men (M=40.54, SD=5.83).

While there were no significant gender differences in ICS, there were significant gender differences within average time production (t[60]=-2.164, p=.039). Women (M=72.37, SD=23.37) significantly overproduced time relative to men (M=61.04, SD=11.95). No significant gender differences were found within average time estimation.

Independent t-tests revealed significant gender differences in total error (t[60]=-3.13, p=.004). Women (M=.341, SD=.246) had significantly greater error relative to men (M=.168, SD=.125).

Correlation Results

Next, a correlation matrix was produced which included all variables, see Table 4. Several significant correlations were revealed through the correlation matrix. As expected, behavioral impulsivity, as measured by the Two Choice task, was significantly correlated with ICS (r= -.311, p=.014), but not with average Mill Hill. A significant correlation was found between Two Choice impulsivity and total BAS (r=-.374, p=.003). Specifically, those participants who scored higher on BAS were less behaviorally impulsive than participants who scored lower on BAS. Two Choice impulsivity also significantly correlated with average time production (r=.434, p=.000). Participants who overproduced time were more impulsive than those participants who underproduced time. Behavioral impulsivity also significantly correlated with total ICS error (r=.428, p=.001). Specifically, those who exhibited more total error in time perception were significantly more impulsive than those with less total error. Interestingly, ICS was correlated with the Barratt Impulsivity Non-Planning sub scale (r=.254, p=.046), but not Barratt total. Therefore, those who reported planning less for near-term future events had faster ICS than those who reported greater planning. However, no differences in ICS were found between those who reported being more impulsive in general (Barratt total) versus those who were less impulsive in general.

In support of the factor analysis of ICS, the correlation matrix reveals a significant, inverse relationship between average time production and average time estimation (r=-.641, p=.000). ICS was correlated with time production (r= -.887, p=.000) and time estimation (r=.923, p=.000), as well as error production (r=-.442, p=.000) and error estimation (r=.338, p=.007). The mean ICS for all participants (M= -.06) indicated that the sample population had, on average, an ICS which was slower than objective time. Participants were 8.7% slower than objective time when producing time (M=65.24), and 2.4% slower than objective time when estimating time (M=73.17). Additionally, both time production and time estimation correlated with total error, (r=.387, p=.002) and (r=.252, p=.049), respectively.

As stated above, the negative correlation between intelligence and impulsivity (r=-.057) was not significant. Therefore, a power analysis was conducted to determine the number of participants necessary to obtain statistically significant results. Using an α=.05, β=.8 and a correlation of .057, the necessary N equaled 2,410 participants. In this study only 62 participants had usable data, which is far fewer than what is necessary to obtain statistically significant results.

Multiple Regression Results

After understanding the relationships from the correlation matrix, various multiple regressions were performed to determine which variables predicted impulsivity. The first variable tested to predict impulsivity was ICS. When tested by itself, ICS predicted 9.7% of the variance in impulsivity (R^2=.097, F[1,61]=6.45, p=.014). See Figure 1 for a scatter plot of ICS and impulsivity.

A second multiple regression was then run using known predictors of impulsivity. Given that BAS total was significantly correlated with impulsivity and gender trended towards significance, both were used as known predictors of impulsivity. Although IQ (average Mill Hill) did not produce significant results within the correlation matrix, it too was included as a known predictor of impulsivity based on results from previous research (Shamosh & Gray, 2008). When combined, intelligence, gender and self reported BAS scores accounted for 17.6% of the variance of the Two Choice impulsivity variable (R^2=.176, F[3, 61]=4.12, p=.01).

It was theorized that ICS would predict impulsivity above and beyond the known factors, and therefore another multiple regression was conducted which once again included ICS. This regression was conducted as a multi-step, hierarchical, linear regression. The first step included the variables: participant sex, intelligence and total BAS. The second step included ICS. As expected, ICS added an additional 7.3% (unstandardized B= -11.05, p=.022) variance above and beyond the 17.6% from the known predictors. The total predictive abilities of the model were 24.9% (F=[4,61]=4.72, p=.002). However, the relationship between ICS and impulsivity was in the opposite direction than anticipated. Specifically, those participants who responded more impulsively on the Two-Choice behavioral impulsivity task displayed a slower ICS, whereas those participants who did not respond as impulsively displayed a faster ICS (r=-.311, p=.014).

Past research has indicated that accuracy in time perception may also be an important factor predicting impulsivity (e.g., Toplak, Rucklidge, Hetherington, John & Tannock, 2003; Meaux & Chelonis, 2003). Therefore, ICS accuracy, as measured by total error, was analyzed. By itself, total error accounted for 18.3% of the variance in impulsivity (R^2=.183, F[1,61]=13.45, p=.001). Next, a multi-step, hierarchical, linear regression was conducted. Participant sex, intelligence and total BAS were included in the first step, and total error was included in the second step. In this regression, total error accounted for an additional 8.9% of the variance (unstandardized B=20.01,p=.011), above and beyond the known predictors, to total 26.5% for the model (F[4,61]=5.14, p=.001). See Figure 1 for a scatter plot of total error and impulsivity.

Finally, a multi-step, hierarchical, linear regression was conducted using both ICS and total error. In the first step, participant sex, intelligence and total BAS were included. ICS and total error were combined in the second step. The predictive abilities of impulsivity for this model were 35.1% ($R^2 = .351$, F[5,61]=6.05, p=.000). Both ICS (unstandardized B=-11.99, p=.009) and total error (unstandardized B=21.4, p=.004) independently predicted behavioral impulsivity.

The final set of multiple regressions performed were with participant sex. Given the independent t-test results which indicated that women trended to respond slightly more impulsively than men (t[60]=-1.99, p=.051), and that women were significantly less accurate in time perception than men (t[60]=-3.134, p=.004), it was necessary to test for interaction effects. Participant sex was coded as 0=male and 1=female, and a multi-step, hierarchical, linear regression was conducted. Behavioral impulsivity was inserted as the dependent variable. Participant sex and ICS were combined in the first step, and the ICS X sex interaction was included in the second step. The analyses revealed that ICS and participant sex predicted 13.1% of the variance in impulsivity (R^2=.131, F[2,61]=4.45, p=.016). The participant sex X ICS interaction slightly added to the predictive abilities of the model (R^2=.132, F[3,61]=2.95, p=.040), but the interaction term was not significant (unstandardized B=2.99, p=.778). Again with behavioral impulsivity as the criterion variable, a second multi-step, hierarchical, linear regression was performed with participant sex and total error in the first step, and the sex X total error interaction in the second step. Total error and participant sex predicted 18.8% of the variance in impulsivity (R^2=.188, F[2,61]=6.85, p=.002). After adding the participant sex X total error interaction to the model, the predictive abilities went up slightly to 19.0% (R^2=.190, F[3,61]=4.52, p=.006). Again, the interaction term was not significant (unstandardized B=4.69, p=.781). Therefore, gender did not interact significantly with either ICS or error in the prediction of behavioral impulsivity.

Discussion

The present research is a valuable addition to the literature involving time perception and impulsivity. Relatively few studies have been designed to investigate the relationship between time perception and impulsivity. Out of the 16 cited, all but one used clinical populations. Therefore, this study added to the limited knowledge about the relationship between time perception and impulsivity, especially among healthy individuals.

The main findings from this research are that ICS significantly predicts behavioral impulsivity above and beyond known factors; though in the opposite direction as expected. Specifically, the slower one's ICS the more impulsive he or she behaves. Total error also predicts impulsivity above and beyond known factors. As expected, greater error in the perception of objective time, the more likely one is to behave impulsively. When combined, ICS and total error produced the best model for predicting impulsivity.

Expected Results

This research was of particular interest because a variety of variables aligned with expectations, while some very intriguing ones did not. To start, the anticipated findings will be reviewed. Through the factor analysis, ICS was extracted from the three measures of time estimation and three measures of time production. This analysis was vital because it indicated that the two time perception tasks were indeed measuring one's ICS. The time estimation trials positively loaded onto ICS while the time production trials negatively loaded onto ICS.

Additionally, the significant correlation between ICS and impulsivity suggested the importance of ICS in predicting impulsivity, consistent with some research incorporating BPD and ADHD patients (Cappella, Gentile & Juliano,1977; Kerns, McInerney & Wilde, 2001; Sonuga-Barke, Saxton & Hall, 1998). Through multiple regression analyses, ICS was found to predict impulsivity above and beyond known factors; however, a negative relationship between ICS and impulsivity was revealed, rather than a positive one.

The significant correlation between total error and impulsivity suggested the potential influence of time perception error on impulsivity, which was referenced in a variety of studies using clinical populations (Meaux & Chelonis 2003; Rommelse, Oosterlaan, Buitellaar Faraone & Sergeant, 2007; Toplak, Rucklidge, Hetherington, John & Tannock, 2003). Again, within multiple regression analyses, time perception error did predict impulsivity above and beyond known factors, and when combined with those factors had a moderate predictive ability.

Unexpected Results

The correlation matrix revealed a few unexpected results. First, intelligence was not significantly correlated with impulsivity, which was predicted based on Shamosh and Gray's (2008) meta-analysis. Self-reported impulsivity and behavioral impulsivity also did not correlate significantly. This was surprising because several previous studied have reported this relationship to be strong (Berlin & Rolls, 2004; Wit, Flory, Acheson, McCloskey & Manuck, 2006; Wittmann, Leland, Churan & Paulus, 2008).

A surprising positive correlation was seen between the Barratt Non-Planning Impulsivity subscale and ICS. Specifically, participants who did not plan as much had a faster ICS, while those participants who planned more had a slower ICS. A significant negative correlation was found between behavioral activation and impulsivity. Those participants who scored higher on behavioral activation were less impulsive on the Two-Choice impulsivity task. Potential explanations for these results will be offered later.

Another unanticipated result was found between gender and impulsivity. Prior work has shown that either men are slightly more impulsive than women (Silverman, 2003) or no gender differences exist in impulsivity (Funder and Block, 1989; Kirby and Marakovic, 1995; Mischel and Metzner ,1962; Mischel and Mischel, 1983; Wit, Flory, Acheson, McCloskey and Manuck, 2007). Yet, the data from the present study indicated that women may be slightly more impulsive that men; though the results were just shy of statistical significance.

Finally, and worthy of particular emphasis, the main finding that ICS was negatively related to behavioral impulsivity was contrary to predicted hypotheses and arguments made by Wittmann and Paulus (2008).

Explanations of Results

As a consequence of the unexpected findings, I have developed a few explanations to potentially better understand these relationships. Intelligence did not significantly correlate with impulsivity as originally anticipated. However, the negative relationship between intelligence and impulsivity was in the correct direction. The undergraduate population recruited for this study does not adequately represent a normal intelligence distribution. Therefore, the limited range in IQ may have affected the correlation between impulsivity and intelligence. Finally, the power analysis revealed that with a correlation of .057, the total number of N needed for statistically significant results would be 2,410 participants. This study only had 62 participants with usable data.

After further reflection about the relationship between BAS and impulsivity, the positive correlation was no longer surprising. One who scores high on BAS seeks rewards and greatly responds to them. Therefore, a participant with high BAS may be willing to wait the necessary time in order to receive a larger monetary reward, as was seen in the Two Choice behavioral impulsivity task. For those participants who scored high on BAS, it appears that the benefit of receiving a greater reward outweighed the longer wait time prior to the reward.

The finding that ICS predicted impulsivity was expected, but the direction of the relationship between ICS and impulsivity was surprising. It was originally hypothesized that a person with a fast ICS would respond impulsively. The research using BDP and ADHD patients revealed varied results, however, Wittmann and Paulus (2008) provided a sound theoretical argument about the positive relationship between ICS and impulsivity; and therefore the above hypothesis was developed. It is possible that by simply using a normal population in this study, a different relationship between ICS and impulsivity was revealed. Yet more research would need to validate this idea.

There is another possible explanation for the negative relationship between ICS and behavioral impulsivity. A person with a slow ICS perceives time slower than objective time. For example, to someone with a slow ICS, an objective 30 minutes may feel like only 20 minutes. Likewise, an objective 24 hours may only feel like 20 hours. As a result, someone with a slow ICS may feel as though there are not enough hours in the day. As a result, he or she may plan out his or her day in an attempt to stay organized. The findings from the Barratt Non-Planning impulsivity scale support this concept; those who were more inclined to planning had significantly slower ICS. Despite planning their time, those with a slow ICS will constantly feel rushed, due to their subjectively limited time. Therefore, while performing a specific task, like the Two Choice, participants may, in the moment, respond impulsively. By responding impulsively, one would quickly complete the current task and therefore be able to move on to other tasks.

Conversely, a person with a fast ICS may perceive an objective 24 hours as perhaps 26 hours. He or she may feel as though s/he had plenty of time to accomplish that which needs to be done. He or she may not plan, and while in the middle of a task may not worry about other requirements yet to be completed. This theory provides an explanation as to why people with slow ICS may act impulsively in the moment. Further research must be conducted to test this theory.

Within the theory mentioned above, which explains the negative relationship between ICS and impulsivity, two different types of impulsivity have emerged: "future oriented" impulsivity and "in the moment" impulsivity. One may report being less impulsive with regards to the future (i.e. he or she plans for the future) and yet respond impulsively when completing a specific task. However, it is possible that one may report being impulsive in both future oriented impulsivity and in the moment impulsivity, or perhaps not impulsive for either type of impulsivity. This, too, must be investigated further. Yet, the distinction between future oriented and in the moment impulsivity may help to explain why self-reported impulsivity did not correlate with behavioral impulsivity in this study.

Future Research

To better understand the relationship between ICS and impulsivity, both ICS and impulsivity must be studied as individual constructs. The variables that may influence ICS, like mood, attentional resources, external stimuli, enjoy-ability of the task, propensity towards procrastination, and perceived deadlines, among others must be investigated. Additionally, the potential distinction between future oriented and in the moment impulsivity must also be studied.

Another important area of research relates to the value of time. For someone with a slow ICS time may seem like a limited resource; he or she never seems to have enough time. Therefore, one with a slow ICS may value time differently than someone with a fast ICS. This discrepancy in how one values time may influence impulsivity. In future research it will also be important to determine how one values time in relation to money, intelligence, power and similar constructs. The value one places on time in relation to other variables may help to further explain the relationship between ICS and impulsivity.

Finally, research on the use of feedback with time perception will help to advance the field. One's perception of time could potentially be influenced through feedback. A person might become more accurate when estimating and producing time if given immediate feedback. One might also be influenced to over- or underestimate time if given bogus feedback. This change in time perception could, in turn, impact impulsivity.

Limitations

This research does have limitations, which may have impacted results. In this study, only one behavioral impulsivity measure was used. While this measure has successfully been used in previous studies (Bjork, Dougherty, Moeller, Harper Scott-Gurnell & Swann, 1999; Dougherty, Bjork, Harper, Marsh, Moeller & Mathias, 2003; Marsh, Dougherty, Mathias, Moeller & Hicks, 2002), other types of impulsivity tasks may produce different findings. The Two Choice is a hybrid of continuous and dichotomous choices. Behavioral impulsivity tasks which are independently continuous or dichotomous may relate differently to ICS, gender and self-reported impulsivity. Therefore, in future research, both continuous and dichotomous tasks might be incorporated. Utilizing both types of impulsivity tasks will enable researchers to better understand the relationship between impulsivity and ICS.

This study used a normal population; however, undergraduate students may not accurately represent the full ranges of intelligence, impulsivity, or perhaps ICS. Based on limited age ranges, demographics, and a lack of cultural diversity, the normal population used in this research may not be entirely representative. Future studies with a variety of normal populations should be conducted.

While this study does have its limitations, it has identified areas of future investigation. It has also helped to advance an area of study that has not previously received much attention. As one can see, the field of time perception has an exciting future, and there are abundant avenues for further research.

Table 1

Summary of Previous Internal Clock speed and Impulsivity Research

Researchers measured internal clock speed and behavioral impulsivity. Their findings regarding the relationship are identified below according to four types of results:
FAST ICS = ICS positively relates to impulsivity
SLOW ICS = ICS negatively relates to impulsivity
NO DIFFERENCE = No difference in impulsivity based on ICS
ACCURACY = Accuracy of time perception is important, not the speed of one's clock (fast or slow)

BORDERLINE PERSONALITY DISORDER	**Results**
Berlin, Rolls & Iverson, 2005	FAST ICS
Berlin & Rolls, 2004	FAST ICS
ADHD	**Results**
Barkley, Murphy & Bush, 2001	FAST ICS
Barkley, Koplowitz, Anderson & McMurray, 1997	SLOW ICS
Toplak, Rucklidge, Hetherington & Tannock, 2003 - Study 1	ACCURACY AND VARIABILITY
Toplak, Rucklidge, Hetherington & Tannock, 2003 - Study 2	ACCURACY AND VARIABILITY
Smith, Taylor, Rogers, Newman & Rubia, 2002	ACCURACY AND VARIABILITY
Sonuga-Barke, Saxton & Hall, 1998	SLOW ICS
Meaux & Chelonis 2003	ACCURACY AND VARIABILITY
Kerns, McInerney & Wilde, 2001	SLOW ICS
Rommelse, Oosterlaan, Buitelaar Faraone & Sergeant, 2007	ACCURACY AND VARIABILITY
Bauermeister, Barkley, Martinez, Cumba & Ramirez, et al., 2005	ACCURACY AND VARIABILITY
West, Douglas, Houghton, Lawrence & Whiting et al, 2000	ACCURACY AND VARIABILITY
Senior, Towne & Huessy, 1979	NO DIFFERENCE
Cappella, Gentile & Juliano, 1977	SLOW ICS
Normal Population	**Results**
Barratt, 1983	FAST ICS

Table 2
Descriptive Statistics for Measured Variables

	Mean	Std. Deviation	Range
Age	19.53	1.42	18-25
Average Mill Hill	19.05	3.11	10-24
Average Time Production	65.24	17.79	29.99-118.11
Average Time Estimation	73.17	26.77	28.67-183.28
Internal Clock Speed	-0.06	0.30	-0.78-0.97
Error in Production	0.23	0.22	0.01-.97
Error in Estimation	0.25	0.26	0.0-1.4
Total Error	0.23	0.20	0.01-.97
Behavioral Impulsivity	8.75	11.66	0-50
BIS	18.48	3.52	12-25.5
BAS Total	39.29	6.15	19-52
Barratt Total	62.81	11.16	41-91
Barratt Non-Planning	23.29	5.94	13-37
Big5 Extraversion	3.23	0.84	1.63-4.88
Big5 Agreeableness	3.96	0.65	2.5-4.88
Big 5 Conscientiousness	3.62	0.71	1.78-4.89
Big 5 Neuroticism	2.50	0.83	1-4.5
Big 5 Openness	3.56	0.60	1.9-4.7

Table 3

Factor Analysis of Time Production and Time Estimation Variables

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.375	72.914	72.914	4.375	72.914	72.914
2	1.046	17.436	90.351	1.046	17.436	90.351
3	.239	3.985	94.335			
4	.205	3.421	97.757			
5	.099	1.652	99.408			
6	.035	.592	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component	
	1	2
Time Production 1	-.899	.233
Time Production 2	-.852	.443
Time Production 3	-.758	.564
Time Estimation 1	.875	.274
Time Estimation 2	.858	.473
Time Estimation 3	.875	.422

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

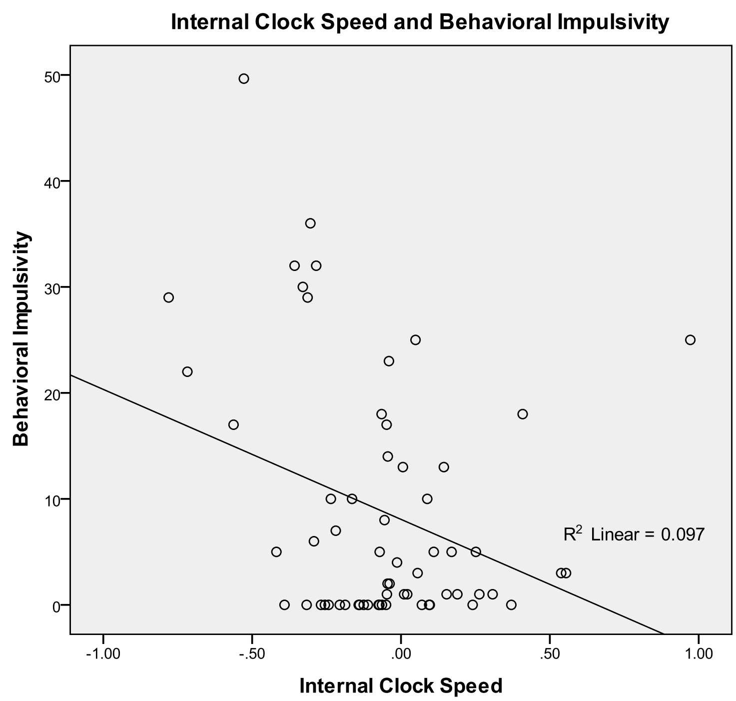
Table 4

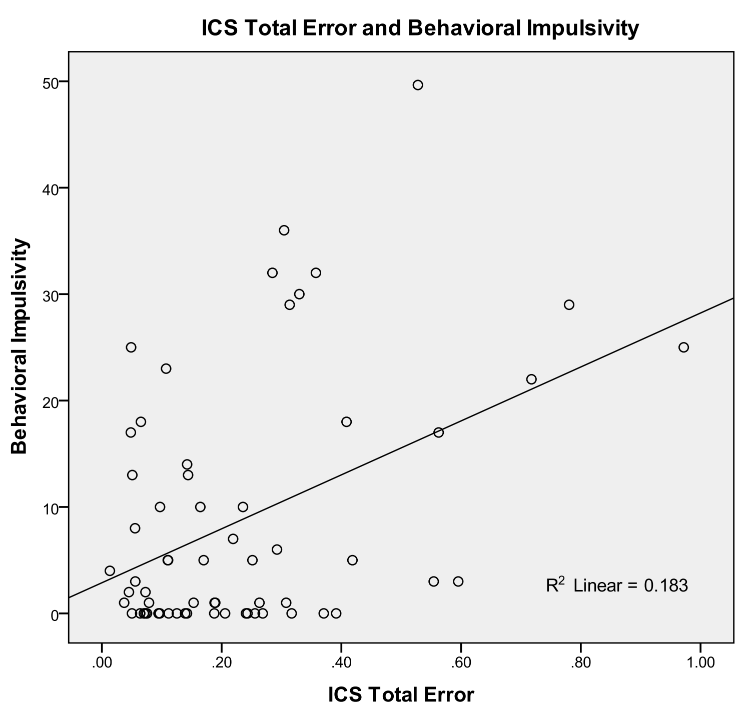
Correlation Matrix of Measured Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Behavioral Impulsivity	1																
2	Average Time Production	.434**	1															
3	Average Time Estimation	-.156	-.641**	1														
4	Internal Clock Speed	-.311*	-.887**	.923**	1													
5	Error in Production	.538**	.630**	-.211	-.442**	1												
6	Error in Estimation	.179	.018	.575**	.338**	.334**	1											
7	Total Error	.428**	.387**	.252*	-.042	.758**	.857**	1										
8	BAS Total	-.374**	-.251*	-.054	.093	-.278*	-.170	-.287*	1									
9	BIS	-.046	.188	-.175	-.199	.091	-.024	.034	-.042	1								
10	Barratt Total	.069	-.227	.155	.207	.003	.124	.054	.024	-.015	1							
11	Barratt Non-Planning	.125	-.201	.254*	.254*	.088	.235	.178	-.098	.080	.868**	1						
12	Average Mill Hill	-.057	.182	-.104	-.154	-.061	.100	.046	-.140	.120	-.011	-.004	1					
13	Big5 Extraversion	-.200	-.213	-.013	.099	-.166	-.207	-.231	.384**	-.289*	.318*	.165	-.342**	1				
14	Big5 Agreeableness	.090	.022	-.159	-.107	-.068	-.123	-.118	.087	-.060	-.163	-.107	-.023	.048	1			
15	Big5 Conscientiousness	-.136	.157	-.265*	-.238	.000	-.280*	-.171	.289*	.114	-.599**	-.727**	-.169	.078	-.044	1		
16	Big5 Neuroticism	.016	.189	-.087	-.147	.120	.072	.139	-.207	.575**	.209	.280*	.092	-.246	-.378**	-.164	1	
17	Big5 Openness	.013	.008	-.025	-.019	-.024	.083	.062	.062	-.141	-.142	-.237	.080	.135	.196	.035	.065	1

Figure 1

Scatter plots of Internal Clock Speed and Impulsivity (above) & ICS Total Error and Impulsivity (below)





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