**“Willpower” Over the Life Span: Decomposing Impulse Control**

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“Willpower” Over the Life Span: Decomposing Impulse Control

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Abstract

Preschool children at Stanford University’s Bing nursery school 40 years ago were tested for their ability to delay gratification on the “marshmallow test”. Longitudinal follow up studies traced the long-term correlates of the observed early life individual differences, focusing on consequential social, cognitive, and mental health outcomes in each decade over the developmental course. As they reach mid-life, individuals from this study consistently high or low in delay ability and impulse control are being assessed by our inter-disciplinary team with fMRI and a variety of cognitive information processing measures to try to further identify and decompose the processes that underlie the phenomena of “willpower” and impulse control. This article reviews key findings from the longitudinal work, and from earlier experiments on the cognitive appraisal and attention control strategies that influence the ability to delay gratification. We also report preliminary findings from the mid-life follow up in progress, and discuss implications of the research for the prediction and potential enhancement of important life outcomes in the aging process.
More than four decades ago, the Bing Longitudinal Study began at Stanford University’s preschool to try to identify and demystify the processes that underlie the phenomena of “willpower.” These phenomena include diverse aspects of control over one’s cognitions, emotions, and actions, particularly the ability to delay immediate gratification and resist impulsive responding. With that goal, experimental studies and long-term longitudinal investigations have been examining children’s abilities to delay immediate gratification. This ability is measured by assessing how long the child could resist settling for a small, immediately available reward (e.g., one mini marshmallow) in order to get a larger reward later (e.g., two mini marshmallows), dubbed the “marshmallow test” by the media (e.g., Mischel, Ebbesen & Zeiss, 1972; Mischel, Shoda, & Rodriguez, 1989; Mischel & Ayduk, 2004).

**Attentional Control and Cognitive Reappraisals Enabling Delay: Early Experiments**

This research began in the early 1970s with a series of experiments designed to elucidate the attentional and cognitive mechanisms that enable young children to delay gratification. These experiments helped to identify the role of attentional control, for example, by self-distraction to reduce the frustration of continuing to wait (e.g., looking away from vs. toward the temptations). The studies also documented the importance of cognitive transformations or reappraisals in which the “hot” (e.g., appetitive, consummatory) features of the tempting stimuli are “cooled” by changing how they are mentally represented (e.g., envisioning the marshmallow as clouds). Such reappraisal processes to “cool” hot stimuli have been shown to be highly effective in enhancing delay of gratification. The same preschool child who yielded immediately to the temptation by
focusing on the consummatory features (e.g., its yummy, sweet, chewy taste) could wait for otherwise unbearable delay periods for the same tempting stimulus by focusing on its non-consummatory qualities (e.g., its shape). These results have been fully described elsewhere (see e.g., Mischel, Ebbesen, & Zeiss, 1972; Mischel, 1974; Mischel, Shoda, & Rodriguez, 1989; Mischel & Ayduk, 2004)). Although these experimental demonstrations have been short-term and confined to brief laboratory situations, they suggest that these strategies required to successfully self-regulate can be taught.

The findings from these experiments and related research also led Metcalfe and Mischel (1999) to propose a “Hot/Cool System Analysis of Delay of Gratification” to explain the dynamics of “willpower.” In that conceptualization, there are two interacting neurocognitive systems that enable self-control and willpower in the execution of one’s intentions. A cool system, likely involving the top-down attentional network that includes the dorsal frontoparietal neural circuit (Corbetta and Shulman, 2002) which underlies processing that is affectively-neutral, flexible, slow, and strategic. It is the seat of self-regulation and self-control (Mischel & Ayduk, 2004; Metcalfe & Mischel, 1999). The other (hot) system, likely mediated by the amygdala and other limbic structures, is the basis of emotionality, fears, and passion; it is impulsive and reflexive, and sometimes it is initially controlled by innate releasing stimuli (and is thus literally under stimulus control). The hot system is fundamental for emotional (classical) conditioning, and it undermines efforts at self-control. The balance between the hot and cool systems is determined by stress, development, and the individual's self-regulatory dynamics. Recent work has successfully extended this model to help individuals cope adaptively with intense negative emotions that require “cooling” in order to facilitate adaptive
psychological adjustment (e.g., Kross, Ayduk, & Mischel, 2005; Kross & Ayduk, 2008).

**Stumbling into Longitudinal Research: The Bing Life-Span Study**

To the surprise of the initiators of this research program, what began as a set of experiments with preschoolers turned into a life-span developmental study. Four decades later this research is continuing to reveal remarkable patterns of coherence in consequential psychological, behavioral, health, and economic outcomes from early childhood to mid-life—the current age of the participants. Given these provocative findings and the methodological advances now available for probing self-control and executive functions with increasing depth, this longitudinal sample provides a unique opportunity for deepening our understanding of the basic neuro-cognitive mechanisms underlying “willpower”. The present paper reports some of our current efforts to take up this challenge.

**Overview of Past Findings.** Participants in the Bing Longitudinal Study come from a sample of more than 300 participants who were enrolled in Stanford University’s Bing preschool between 1968 and 1974. Since the original testing, the ability of these participants to pursue long-term goals in the face of immediate temptation has been assessed once every decade. Participants have now reached their late 30s and early to mid 40s, and information about their life outcomes, such as their occupational, marital, physical health, and mental health status are continuing to become available. The findings have surprised us from the start, and they continue to do so. For example, preschoolers who delayed longer relative to other participants in the original “marshmallow test” earned higher SAT scores and exhibited better social-cognitive and emotional coping in adolescence (Mischel, Shoda, & Peake, 1988; Shoda, Mischel, & Peake, 1990).
adults, these participants continued to have better cognitive-social functioning, and better educational and economic life outcomes than did their low-delaying peers (Ayduk et al., 2000).

The high-delay individuals also were buffered against the development of diverse mental health problems: they used cocaine less frequently, were less likely to suffer from low self-esteem and self-worth (Ayduk et al., 2000), and had fewer features of borderline personality disorder than did matched controls with similar dispositional vulnerabilities (Ayduk et al., 2008). Parallel findings come from diverse demographic populations, including middle-school children in the South Bronx, N.Y. (e.g., Ayduk et al., 2000; Mischel & Ayduk, 2004) and children in a summer residential treatment program for youths at high risk for problems of aggression/externalization and depression/withdrawal (e.g., Mischel & Shoda, 1995; Rodriguez et al., 1989). For example, spontaneous use of self-control strategies in the delay task (e.g., looking away from the rewards and using self-distraction) predicted lower verbal and physical aggression as directly observed over six weeks in the summer camp study (e.g., Rodriguez et al., 1989; Wright & Mischel, 1987, 1988).

In search of the mechanisms underlying long-term stability in individual differences in self-control abilities

The early experiments examining delay of gratification showed that mental representations that are “hot” or appetitive (consummatory) hinder delay and are ineffective because they make it too difficult to resist the prepotent response of settling for the immediately available treat. In contrast, representations based on attention to the “cool,” cognitive, abstract aspects of the situation have the opposite effect. Thus, delay
ability in this paradigm depends critically on the aspects of the situation to which the child attends, the mental representations that are activated in working memory during the waiting period, and the degree of control the child has over his or her response behavior. It is precisely these three aspects of cognitive control that we have been pursuing in ongoing work with the Bing sample.

_Cognitive control mechanisms._ How is cognitive control achieved? The weight of evidence, presented in a meta-analysis of 41 neuroimaging studies of a variety of tasks measuring cognitive control, such as the Flanker, Stimulus-response-incompatibility (SRIC), Go-no/go, Simon, Stop-signal, and Stroop tasks (Nee, Jonides, & Berman, 2007), does not favor the view that there is a unitary mechanism. The activation peaks in these tasks are widely dispersed in the brain, suggesting that there are multiple mechanisms of control. This conclusion is supported by the oft-reported low behavioral correlations among tasks that allegedly recruit inhibitory mechanisms (Earles et al., 1997; Grant & Dagenbach, 2000; Kramer et al., 1994; Shilling et al., 2002; Tipper & Baylis, 1987). Thus, both imaging and behavioral evidence suggest that processes involved in resolving interference come from a “family of functions” rather than from a “single unitary construct” (Friedman and Miyake, 2004; Dempster, 1993; Harnishfeger, 1995; Nigg, 2000).

Guided by these analyses, for the first time in the four-decade long Bing Longitudinal Study we are currently collecting data on both behavioral and cognitive, and neural functioning (via functional and structural brain imaging) in the participants.

_Current data collection._ Before examining the brain functioning underlying self-regulation, we sought to obtain information about the participants’ cognitive control
abilities using behavioral tasks designed to measure cognitive control. Because the participants are now widely dispersed across the globe, we mailed laptop computers preprogrammed with software for tasks designed to assess cognitive control. We focused on two subsamples of the Bing study: participants who were consistently above average in their self-regulatory abilities, beginning with their performance on the delay of gratification task in preschool in the early 1970s, through the three follow-up assessments conducted in 1984, 1993, and 2003; and those who were consistently below average throughout the first four decades of their life. Our rationale for focusing on these participants is that if individual differences in self-control reflect differences in the basic operation of the brain, these may be most clearly seen by comparing individuals with life-long trajectories of stably high, or stably low, self-control. Indeed, these individuals have a four-decade long “track record” of high vs. low self-control.

One hundred and seventeen individuals met the criterion of being either consistently above average or consistently below average in self-control in their original delay of gratification performance as well as in their self-control ability in subsequent follow-ups. In these follow-up assessments, self-regulation was assessed using items from the California Child Q-set (CCQ) in 1984 (when the participants were in their late teens), in 1993 (when they were in their late twenties), and in 2003 (when they were in their late thirties). These 117 individuals were invited to participate in the current follow-up (we did not include their 1984 score in this requirement because of the relatively small sample size in 1984). Of those who were invited, 57 agreed to participate, were sent laptop computers, completed the tasks, and returned them. Of the 57, 31 were from the “consistently high self-regulation” group, and 26 were from the “consistently low self-
regulation” group. Figure 1 shows the self-control trajectories across these three waves of follow-up assessments for these 57 consistently high and consistently low participants. The vertical axis represents the self-regulation indices, standardized within each assessment period. The horizontal axis represents the year in which the self-regulation data were collected, including the initial preschool assessment that took place between 1968 and 1973. The two lines represent the average developmental trajectories for those participants whose preschool delay time was consistently above mean (shown in blue), and those who were consistently below mean (shown in red).

The figure illustrates that the two subgroups we targeted in our current data collection clearly differ from each other at every assessment during the past four decades. While this is not surprising because they were chosen on the basis of being above or below across the follow-up waves, the fact that many of the participants fell in either of these groups, and that their means at each data point were many standard errors apart, reflects the overall stability of individual differences in self-regulation.

**Preliminary Findings: Behavioral Indices of Cognitive Control**

Are life-long patterns of high vs. low self-regulation related to behavioral indices of cognitive control? Specifically, we examined the following three aspects of cognitive control: (1) blocking the entry of unwanted information (e.g., shutting out information by paying attention to something else); (2) suppressing unwanted thoughts (e.g., by thinking about something else); and (3) stopping themselves from acting upon salient cues (e.g.,
inhibiting a response or impulse). In order to assess them, we used a set of laboratory procedures designed to measure each process, as described below.

**Evaluating the ability to block the entry of unwanted information with the Ignore Task.** We used a version of Sternberg’s (1966) item-recognition task to assess the first two of the three aspects of cognitive control described above (Jonides, Smith, et al., 1998, Jonides, Marshuetz, et al., 2000; D’Esposito et al., 1999; Thompson-Schill et al., 2002; Nelson et al., 2003; Nee et al., 2007). Specifically, we modified this task to allow us to study interference-resolution in perception and working memory (Nee & Jonides, 2008, 2009).

Participants were presented with a set of 4 words for .5 seconds, half of which were printed in teal and half in blue. Prior to each trial, participants were given a cue (the word “teal” or the word “blue”) telling them which 2 of the words in the upcoming display were relevant on that trial. Immediately after seeing the display, participants were given a probe word and had to decide whether it matched one of words in the relevant color. If the probe did not match one of the words in the relevant color, it might have been a word originally presented in the other color. As a control, the probe might have been a word that had not been presented on the current trial or on any of the three previous trials. A comparison between these two types of non-matching probes reveals how successfully participants were able to “ignore” (hence the name of the task) the irrelevant information.

This paradigm serves as the basis for our examination of whether adults who could or could not delay gratification as children differ in their effectiveness in resolving interference at the time of original perception of information (encoding).
Evaluating the ability to control unwanted information with the Suppress Task.

We also designed a task that assessed how effectively participants could “suppress” information that already entered working memory. The design was similar to that of the Ignore task. For the Suppress task, participants were presented with 4 words, two in teal and two in blue. After the display was encoded, a cue appeared telling subjects which two of the words (either both teal words or both blue words) to forget. After that, a probe appeared. Again, if the probe did not match the relevant words, it could be one of the words that was to be forgotten or some control word that had not appeared recently in the experiment. By comparing these non-matching trials, this task provides an opportunity to assess how well participants can suppress irrelevant information that has already entered working memory but is no longer relevant. Figure 2 shows the train of events on a typical trial.

The data collection is still on-going. So far, however, in a sample of 57 Bing participants, we found no clear association between preschool delay time and participants’ performance on the Ignore task. As for their ability to control contents of working memory, we found a trend of low-delay participants making a greater number of errors on the Suppress task (figure 3). Recall that the participants were selected on the basis of their either consistently high, or consistently low, self-regulation trajectory over the last four decades. Thus, those with above average preschool delay time in this sample are a subsample of such participants who also maintained above average self-regulation.
indices during the subsequent decades; similarly, those with below average preschool delay time in this sample are a subsample who also remained below average self-regulation so far in their lives.

Cognitive control of prepotent reaction to “hot” stimuli. The go/no-go task (Luria, 1961) is a measure of cognitive control that requires over-riding a prepotent response. This task is computer-administered and requires participants to press a button whenever a target (go) stimulus is present, but not to respond to an infrequently presented nontarget (no-go) stimulus. We included this task because of our interest in determining the extent to which the ability to delay gratification involves the ability to stop oneself from acting (Eigsti et al, 2006). That is, performing well on this task requires not only pressing a button in response to the go stimulus, but also withholding a response to the no-go stimulus. Therefore, performance on the no-go trials was of particular interest.

We administered an adapted version of the traditional go/no-go task (Hare et al 2005) in which emotional facial expressions were used as stimuli (i.e., emotional go/nogo task). Specifically, stimuli were digital photographs of happy and fearful expressions from eight individuals (four female and four male) obtained from the NimStim set (available at www.macbrain.org; identities of the faces used were: 8, 10, 14, 16, 27, 36, 39, and 45). Hare et al. (2005) suggested that participants have a more difficult time withholding a response when the no-go (nontarget) stimulus is a happy expression because happy faces are positive approach-related stimuli, while fearful faces are
negative and alarming stimuli. Thus, while we were interested in the no-go trials in
general, we were particularly interested in performance on the happy no-go trials as these trials were hypothesized to require greater self-control in order to successfully inhibit an approach response.

Figure 4 is a schematic representation of a block of trials in which fearful expressions were the go stimuli and happy expressions were the no-go stimuli.

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Insert Figure 4 about here

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Participants were instructed to respond to the target facial expression (fearful or happy) by pressing the space bar on a keyboard. Stimuli were presented for 500ms with an interstimulus interval (ISI) of 1000ms, during which a fixation cross was presented on the screen. Therefore, trial length was 1500ms. Two 160-trial runs comprised the task. In one run, the go stimulus (target) was happy expressions. The go stimulus (target) was fearful expressions in the other run.

Thus far, we have collected data on this task from a sample of 57 Bing participants, and data collection is still on-going. Preliminary results suggest that the accuracy on trials in which the happy expressions were the no-go stimuli is significantly related to self-regulatory abilities over the first four decades of their lives, starting in preschool, as shown in Figure 5. Among the 56 participants with valid go/no-go data (one participant’s data were not used because of extremely long latencies), the correlation was $r = .27$ ($p < .05$). Delay of gratification at age four did not appear to be related to accuracy.
on trials in which fearful expressions were the no-go stimulus or to reaction times associated with any trial types.

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Insert Figure 5 about here
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In addition, we also administered the Barratt Impulsiveness Scale (BIS-11), a widely used measure of impulsivity consisting of 30 items assessing attentional, motor, and nonplanning impulsiveness. As shown in Figure 6, participants, accuracy in happy no-go trials was negatively and significantly correlated with this measure of impulsivity ($r = -.37, p < .01$). The correlation between standardized delay and BIS-11 scores was -.58, $p < .001$ ($N = 56$).

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Insert Figure 6 about here
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Exploring brain functions and structure underlying life-long patterns of self-regulation

Ultimately our goal is to specify the neural correlates of these processes using magnetic resonance imaging studies that are underway, although we are still in an early stage of data collection. Prior research has elucidated areas of the brain that become differentially activated when people engage in the three processes described above (blocking unwanted information, suppressing unwanted thoughts, and inhibiting responses), as well as the connections among areas of the brain that seem to play a key role in these tasks. We are currently assessing these functional and anatomical features to examine whether they are related to these three aspects of effective self-control. Specifically, resolution of interference between goal irrelevant (but alluring) and relevant
(and long-term goal-specific) information. There is by now a well-specified set of brain regions that have been discovered in previous research that can be associated with the ability to resolve interference between relevant and irrelevant information at the time of encoding, at the time information is in working memory, and at the time when one is producing a response. For example, the right inferior frontal gyrus has been well-documented as a critical region in resolving interference in the go/no-go task which involves response interference (e.g., Casey et al., 2002; Aron & Poldrack, 2006). Likewise, the left inferior frontal gyrus region has been implicated when interference occurs after information has entered working memory (e.g., Jonides & Nee, 2006). And the dorsolateral prefrontal and posterior parietal regions appear critical to resolving interference at the time of encoding (e.g., Casey et al., 2000; Nee & Jonides, 2008).

These tasks share a key feature with the delay-of-gratification task used in our longitudinal studies: in all these cases, prepotent information interferes with other goal-specific information, thus requiring processes of cognitive control to resolve the interference. Specifically, we predict that participants with low levels of self-control, compared with their high-control counterparts, will be characterized by less activity and less refined connectivity (e.g., less myelination and orientation regularity) in frontostriatal (Liston et al., 2006; Casey et al., 2007) and frontoparietal circuitry (Nagy, Westerberg, & Klingberg, 2004) during performance of the cognitive control tasks. We are testing this prediction by performing diffusion tensor imaging (DTI) and functional MRI. Participants in this study have been invited to the Lucas Center for Imaging at Stanford University and only a few have been scanned to date.
Finally, the participants are reaching middle adulthood and the most productive years of their lives. Therefore, we are continuing to assess consequential outcomes, including occupational and marital status, social, cognitive, and emotional functioning, as well as mental and physical health and behavior patterns relevant to mental and physical health and economic and social well-being.

**Implications and next challenges: Advancing NIA goals**

Work by our team and other investigators shows that willpower (adaptive self-regulation) in young children and adolescents is facilitated by a set of specific cognitive and affective strategies that allow them to control their attention strategically and to transform their thoughts, all in the service of effectively resisting impulsive responding and delaying immediate gratification for the sake of later, more valued, future goals. These cognitive-affective strategies serve to “cool” and thus reduce the emotion-eliciting power of the impulse-triggering temptations and frustrations that otherwise undermine even people’s best intentions to control their own impulsive behavior in light of delay consequences.

Overall, decades of research on delay of gratification suggest an emerging view of “willpower” and impulse control (e.g., Mischel et al., 1989; Mischel & Ayduk, 2004; Kross, Mischel & Shoda, in press). Considered collectively, the results of the laboratory experiments, conducted when the Bing study participants were in preschool, suggest that the concept of willpower can be decomposed into at least two general classes of neurocognitive processes: (1) attentional and inhibitory processes, often referred to as *cognitive-control processes*; and (2) *reappraisal processes*, that control the mental representation in working memory, transforming a tempting representation into another
(e.g., a 5-year-old might succeed in delaying gratification by transforming his/her perceptual representation of a single marshmallow into a representation of a *pictured* marshmallow).

We suggest that the pre-schoolers who were high-delayers made more use of certain inhibitory processes than did those who were low-delayers, and it is this difference in inhibitory ability that persisted into adulthood and led to the sequelae of being able to delay gratification and the advantageous health-protective outcomes and adaptive social-cognitive development that followed. The relation we propose between cognitive control and willpower, as manifested in the delay-of-gratification studies and their resulting sequelae, is this: Willpower requires skill in overcoming tempting immediate rewards, distractions, and frustrations in favor of greater but delayed rewards. This skill, in turn, requires encoding only information from the environment that is relevant, keeping wanted information active in working memory and suppressing unwanted information, and selecting desired responses while withholding responses that are not optimal. Findings so far are encouraging but still tentative: with further follow-up assessments we hope to test these hypotheses with greater precision.

*From preschool impulse control to social and economic behaviors in aging.* With NIA goals in mind, we are also including genetics in this project, as well as gathering other types of aging-relevant data from our participants now, ranging from brain imaging data to information about such economic behaviors as savings, retirement planning, health care planning/protection, and mental and physical health. By obtaining such information on our unique longitudinal sample, we are laying the groundwork for extending the study into the coming decades to identify factors that underlie lifespan
longitudinal trajectories of self-regulation and consequent behavioral outcomes. Of particular interest for understanding economic behavior over the life span, we are including standard measures of temporal discounting, thus enabling systematic comparison of such measures with the predictive and explanatory value of our behavioral measures of delay of gratification and self-control. We are now well-positioned to conduct such assessments over the life span, obtaining comprehensive data that are relevant for our original Bing participants now at mid-life, their young children, and their parents (in many cases still surviving) now in their 70s, thus spanning three generations.

**Concluding remarks.** Taken collectively, findings over many decades from the Bing study converge with those from many other studies of “willpower” and executive functions at the social-cognitive (e.g., Mischel & Ayduk, 2004), and brain (Casey et al., 1997; Hare et al., 2005) levels point to a clear, albeit still tentative, set of conclusions. The skills and motivations that enable the phenomenon of “willpower”, and particularly the ability to inhibit prepotent “hot” responses and impulses in the service of future consequences, appear to be important early life markers for long-term adaptive mental and physical development. They predict a wide variety of consequential life outcomes, including social and economic well-being and higher educational and achievement levels. Further, these skills seem to have long-term protective effects that may importantly influence how a variety of hugely problematic dispositional vulnerabilities develop and play out (e.g., high delay ability early in life predicts fewer features of borderline personality, less substance use). Ultimately it may be possible to target and harness the underlying mechanisms into readily teachable interventions for sustained and consequential behavior change. Our research currently seeks to identify, develop and test
the tool kit of basic cognitive skills that enable willpower. Most encouraging, the
cognitive and affective strategies that underlie this aptitude may be fairly easy to teach
and learn (e.g., Bandura & Mischel, 1965; Mischel, et al., 1989; Mischel & Ayduk,
2004).

Relevant to NIA goals, the Bing cohort and the data it has already yielded
provides a unique basis for future studies of the ageing process as these participants move
into the next phase of the life cycle. The possibility that the self-regulatory competencies
reflected in the ability to delay gratification exert benign and protective influences on the
ageing process seems a particularly exciting prospect for further investigation. Such work
is certain to benefit from inter-disciplinary teams working at multiple levels of analysis
from the social cognitive and behavioral, to the neural, to the genetic.
Author Notes

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collection from the Bing longitudinal study that yielded the new data reported here.
References


Figure 1

Life-long trajectories of high vs. low self-regulation groups

Note: Bars around the mean are standard errors
Figure 2

A schematic of the "Suppress" task showing the timeline of events on three typical trials. A memory set in two colors is presented, followed by a cue to forget half the items in the indicated color. Then one of three sorts of probes ensues: a probe that matches an item in memory, a probe that never appeared on that trial, or a probe that was one of the items to be forgotten.
Figure 3

Supp Effect ACC by Standardized Delay Time

\[ y = 0.0119x - 0.0475 \]
\[ R^2 = 0.01897 \]

Supp Effect

Linear(Supp Effect)
Figure 4. Temporal layout of the emotional go/nogo task for the condition in which happy expressions were the nontargets.
Figure 5

Plot of correlation between nogo performance for happy expressions in adulthood and same participants standardized delay score at age 4 years.
Figure 6

Happy Nogo ACC by BIS-11 Total*

\[ y = -0.0031x + 1.1253 \]

\[ R^2 = 0.1348 \]