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Behavioral and neural correlates of delay of gratification 40 years later

B. J. Casey,^{a,1} Leah H. Somerville,^a Ian H. Gotlib,^b Ozlem Ayduk,^c Nicholas T. Franklin,^a Mary K. Askrend, John Jonides,^d Marc G. Berman,^d Nicole L. Wilson,^e Theresa Teslovich,^a Gary Glover,^f Vivian Zayas,^g Walter Mischel,^{h,1} and Yuichi Shoda^{e,1}

^aSackler Institute for Developmental Psychobiology, Weill Cornell Medical College, New York, NY 10065; ^bDepartment of Psychology, Stanford University, Stanford, CA 94305; ^cDepartment of Psychology, University of California, Berkeley, CA 94720; ^dDepartment of Psychology, University of Michigan, Ann Arbor, MI 48109; ^eDepartment of Psychology, University of Washington, Seattle, WA 98195; ^fLucas Imaging Center, Department of Radiology, Stanford University School of Medicine, Stanford, CA 94305; ^gDepartment of Psychology, Cornell University, Ithaca, NY 14853; ^hDepartment of Psychology, Columbia University, New York, NY 10027

Correspondence: E-mail: bjc2002@med.cornell.edu, wm@psych.columbia.edu, or yshoda@u.washington.edu, krishna.miyapuram@cantab.net, Tel: +39 331 946 9575

Krishna Prasad Miyapuram

Center for Mind/Brain Sciences, (CIMeC - Centro Interdipartimentale Mente/Cervello), Università degli Studi di Trento, Via delle Regole 101, 38060 Mattarello (TN), ITALY

Background

Delayed gratification refers to the ability to wait over a period of time to receive a desired outcome. Given a choice between \$10 today and \$11 tomorrow, many people would opt for the immediately available reward.¹ In an experiment with pre-school children four decades ago, Mischel and colleagues² offered one piece of the preferred confectionary (e.g. a cookie) whenever the child wanted to eat it. However, the participants in that study were informed that if they could wait until the experimenter would return back (which could be up to 15 minutes), then they could have two pieces of the confectionary. Inter-individual differences were measured by the time for which the child could actually wait before giving in for the immediate, alluring reward. These measures were later found to be reliable predictors of the child's scholastic success and other factors as adolescents². As an extension of their longitudinal study over the life-span, a brain imaging study was conducted on a subset of individuals from the original study group. Confectionary items such as cookies would no longer be highly desirable with the participants grown up as adults by now. Hence, social cues of faces with emotional expressions (e.g. happy, fearful) were used in the current study. The inter-individual differences can be explained by different cognitive strategies used by different participants. For example, focusing on the "hot" properties (e.g. appetitive and consummatory aspects) of the reward made the child prone to temptation. By refocusing their attention on the "cool" properties (e.g. shape), the children could wait for relatively longer times. The findings from the brain imaging study are interpreted in terms of a hot/cool system hypothesis. Corresponding brain activations were found in regions previously implicated in cognitive control (inferior frontal gyrus) and in processing immediate rewards (ventral striatum).

Study design

The present study uses a cognitive control task (the go/nogo task) with two versions. In the cool version of the task, participants had to make gender discriminations, of facial stimuli with neutral expressions, by pressing a button (go trials) to tar-

get faces and withholding the button press (nogo trials) for the non-target faces. In the hot version of the task, participants had to discriminate between happy and fearful faces. The results were analyzed by grouping the participants as low and high delayers based on their scores in the original pre-school study. Two experiments were performed, the first one was a behavioral study with a larger cohort (N = 59) and the second was a brain imaging study on a sub-group from the behavioral study (N = 27). Behavioral results indicated that the reaction times and accuracy for go trials did not discriminate between the low and high delayers for both the cool and hot versions of the go/nogo task. On the nogo trials (i.e. withholding of response presumably by exerting self-control), the false alarm rates were comparable between the two groups of participants in the cool version of the task. However in the hot version of the task, the low delayers performed poorly than the high delayers, particularly for the happy faces rather than the fearful faces. Given that the behavioral study revealed that the cool version of go/nogo task does not discriminate between the low and high delayers, brain imaging was done only during the hot version of this task.

The primary finding from brain imaging study was that the right inferior frontal gyrus was more activated during nogo trials compared to go trials. Follow-up analysis indicated that the high delayers exhibited greater activation in this region for nogo trials compared to low delayers. On the contrary, activation in the ventral striatum was greater for low delayers compared to high delayers in the nogo trials for happy faces alone. The differential involvement of fronto-striatal areas for the two groups of delayers provides further support towards the relative stability of delay of gratification across life-span. The study replicated well-known findings on other aspects of the study namely involvement of contralateral primary motor cortex and ipsilateral cerebellum for go compared to nogo trials (i.e. whether a response was required or not). Similarly fearful compared to happy faces revealed activations bilaterally in the medial temporal lobe (in the vicinity of amygdalae).

Implications

The findings as part of a longitudinal study³ contribute to our understanding of individual differences in self-control. The participants selected in this study showed consistent behavior as children and as adolescents. Particularly the behavioral findings suggest that the delayed gratification scores are not just related to cognitive control in general, but more particularly geared towards compelling cues as revealed by different findings from the cool and hot versions of the go/nogo task. Similarly, activation in ventral striatum, previously implicated in processing immediate rewards differentiated the two groups of delayers for happy faces alone. The novelty of the findings lies in designing experiments that could reveal individual differences in children and in adults, separately and yet be able to identify the relation between these two seemingly different procedures. However as a stable trait, the delay of gratification possibly indicates the cognitive strategies used by individuals during performance of various types of tasks throughout life-span. Further extensions of this research could be geared towards how individuals can be trained to adapt

different cognitive strategy and thus transform a low delayer to a high delayer³. Experimental paradigms can also be used over a more short-term basis such as the intertemporal task¹ offering choices between a smaller immediate reward and a larger later reward. Particularly neuroeconomic research¹ has indicated that participants often exhibit preference reversals when both the immediate and delayed prospects are further delayed over a longer time span. Together the findings have to be reconciled towards on strategies that help individuals resist the now and prefer long-term goals.

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References

1. McClure SM, Laibson DI, Loewenstein G, *et al.* Separate neural systems value immediate and delayed monetary rewards. *Science* 2004; 306: 503–507.
2. Mischel W, Shoda Y and Rodriguez MI. Delay of gratification in children. *Science* 1989; 244: 933–938.
3. Mischel W, Ayduk O, Berman MG, *et al.* 'Willpower' over the life span: decomposing self-regulation. *Soc Cogn Affect Neurosci.* 2011; 6: 252–256.