4.3 Expectations and placebo effects in the context of cognitive training

Jocelyn Parong, Susanne Jaeggi, Aaron Seitz, and C. Shawn Green

Introduction

Basic cognitive skills such as attention or memory are important for most, if not all, of our daily activities, from remembering grocery lists, to keeping track of conversations, to carrying out specialized work-related or academic-related tasks. As such, there has been great interest in whether and how these basic cognitive skills can be improved through behavioral training. Over the past few decades, the proposition that by improving basic cognitive skills we could in turn produce significant real-world benefits has spurred dozens of experimental intervention studies aimed at improving a multitude of cognitive functions, including working memory (i.e., the active storage and manipulation of information),[1] selective attention (i.e., the ability to focus on particular inputs for further processing, while simultaneously ignoring irrelevant information),[2] and fluid intelligence (i.e., the ability to reason and problem solve).[3] Not only could enhancing such functions have a significant impact among populations who experience challenges in those domains, such as those with attention-deficit hyperactivity disorder or Alzheimer's disease or related dementias, but also could benefit typically developing individuals in everyday real-world situations.

Cognitive training is the superordinate category label that has been applied to all interventions designed with the purpose of enhancing cognitive skills, from music training to mindfulness meditation.[4] For the purposes of this chapter though, we will utilize the term *cognitive training* to specifically refer to the segment of the field that has employed various forms of computerized training, including commercial or custom video games or video game-like programs, as these strongly share the set of methodological considerations and areas of debate that we will examine here.[5–8] One major area of debate focuses on whether the observed changes in cognition produced by cognitive training are (1) of a large enough magnitude and (2) sufficiently broad to be practically meaningful.

Indeed, one of the more consistent findings across the learning sciences is that if individuals are given dedicated training on a particular task, they tend to improve on that very task. However, they do not then always show improvements in other tasks—even ones that seem to be quite like the one they trained on. This phenomenon has sometimes been referred to as the "curse of specificity"[9] because for training to produce real-world improvements, it is critical that the benefits extend not just beyond, but well beyond, the confines of the computerized training tasks. For example, imagine that a person receives dedicated training on the game Tetris, where players must mentally rotate and then organize 2D puzzle shapes as they descend the screen to form complete lines on the bottom. It is almost certainly the case that the individual will become better at playing Tetris as a result of this training. The bigger question is whether they would also then, for instance, show enhanced performance on mental rotation tasks in a laboratory setting, such as on the Shepard and Metzler 3D mental rotation tasks[10] and/or performance on real-world tasks that require the use of mental rotation, such as some math problems[11] or navigating in an unfamiliar environment.

The consensus in the field to date is that there is overwhelming evidence that computerized cognitive training improves performance on identical or nearly identical tasks (e.g., speed-of-processing training using a Useful Field of View training program increases performance on closely related laboratory measures of processing speed).[12] There is less, but still compelling evidence of improved performance on moderately similar tasks (e.g., working memory training improves performance on fluid intelligence tasks, or action video game training improves top-down attention).[2,13] And finally, there is much more uncertainty about whether computerized cognitive training consistently produces improved performance on vastly dissimilar tasks, especially real-world tasks.[7]

The very nature of cognitive training interventions makes placebo effects a possible concern

Though previous cognitive training studies have shown some promising outcomes for improving cognitive functions, the mechanisms of exactly how and when transfer from cognitive training occurs is still an ongoing research question. One popular critique of the field has posited that participants' expectations regarding outcomes play a major role in the positive outcomes that have been observed. In other words, it has been argued that perhaps participants are showing improvements in cognitive abilities following training not because of anything to do with the training itself, but instead they are showing improvements simply because they expected that the training would enhance their cognitive skills.

In considering this idea, it is worth briefly examining the basic premises and methods underlying cognitive training interventions (for a more extensive discussion, see Green et al.[5]). In most cognitive training studies, one group of participants is assigned to a treatment condition, which practices a computerized cognitive intervention (e.g., a video game or other computerized program) for a certain amount of time, while another group of participants is assigned to a control condition, which either completes no training at all (i.e., what is sometimes called a no-contact or waitlist control group) or more ideally, completes an activity assumed to lack the "active ingredient" that would induce changes in the targeted component of cognition in the same way the treatment intervention would. Posttreatment cognitive abilities, relative to baseline pretreatment cognitive abilities, are then compared between the treatment and control conditions. If the treatment group improves more than the control group, it can be concluded that the cognitive intervention (more specifically, its active ingredient, given an appropriate active control condition) was effective. However, ensuring that the active ingredient is the *only* element that differs between the treatment and control groups is particularly difficult in the case of cognitive training interventions. If a medical researcher is examining the efficacy of a particular drug compared to a placebo control, they can carefully match the appearance of the real pill and control pill (e.g., a sugar pill). If the research team and participants remain unaware of the condition to which participants have been assigned, any differences in outcomes between the experimental and control groups can be attributed solely to the active ingredient in the experimental drug. This is most often referred to as a double-blind design, in that neither the research team nor the participants can determine what condition participants have been assigned (although note that the use of the word *blind* in this context can be considered ableist and, thus, below we use alternative terms, such as *masking*).

To move in this methodological direction, researchers in the cognitive training domain have frequently attempted to use control conditions that are very similar to the true intervention, such as manipulating a custom racing game to include either multi-task or single-task requirements,[14] by comparing visual n-back training to auditory n-back training,[15] or by comparing easier and harder versions of the same task.[16] However, it remains the case that creating an outwardly identical active control activity that looks like the treatment intervention without the active ingredient is literally impossible; without the active ingredient, the mechanics of the game or program (e.g., content, challenges, and strategies) will *necessarily* change. Additionally, cognitive training interventions are designed to put at least some strain on certain cognitive systems, which may produce fatigue that participants can identify and make them aware of being in a certain cognitive training intervention.[17] It is interesting to note that a similar issue almost certainly exists in medical studies—even those that are referred to as double-blind (i.e., that participants form expectations or become aware based upon how they feel after taking their respective pills). Most active drugs will induce at least some side effects, which can in turn be used by participants to "guess" their condition.[18] Some researchers have argued that an ideal control pill should thus induce some side effects (if not identical side effects—e.g., rather than a sugar pill, or an antihistamine that would cause dry mouth) to ensure that participants cannot use the presence or absence of side effects to form intuitions about the condition to which they have been assigned.[19]

Given that differences in the look and feel of the true intervention and the active control cannot be fully eliminated in cognitive training designs, if these differences in look and feel in turn produce differences in expectations regarding the most likely outcome of the two forms of training, improvements in one condition over another may be due, at least in part, to differential placebo effects across conditions.[17] And indeed, there is reason to suspect that many people either carry positive expectations of cognitive training interventions before entering a study or quickly form expectations upon being exposed to the training tasks. For example, Rabipour and Davidson[20] asked participants to rate how successful they believe computerized cognitive training would be at improving their general cognitive function on a scale from 1 (completely unsuccessful) to 7 (completely successful). They found that 69% percent of respondents gave ratings of 5 or higher, suggesting that many people have existing positive expectations of cognitive training even before experiencing any training. They also found that these expectations can be manipulated by presenting evidence either advocating for or against brain training programs. Other studies have corroborated this finding, with most participants leaning toward positive views of cognitive training.[21–22]

Similarly, Boot and colleagues[23] asked participants to watch a video about either an action video game (Unreal Tournament; a game that has been used in the attempt to drive cognitive enhancements) or a game commonly used as a control game in cognitive training studies (Tetris or The Sims). They were then asked to read descriptions of a list of cognitive and perceptual laboratory tasks and indicate whether they thought the game they viewed would improve performance on each task. Participants expected that the action video game would lead to greater improvements in some tasks, such as tasks that measure visual spatial attention (the Multiple Object Tracking task, Useful Field of View), which generally aligned with the published results of cognitive training interventions (i.e., that action video games improve visual attention skills).[13] Another study found similar results, showing that participants who were trained on action video games generally expected greater improvements than those trained in a control game.[24]

All told, then, the available data do suggest that participants can and do form differential expectations about cognitive interventions. This in turn leads to the question: Do the expectations have practical consequences? In other words, Do they affect behavioral outcomes?

Are expectations related to behavioral outcomes in cognitive training?

To date, only a few studies have directly measured participants' expectations using self-report measures and compared those to actual outcomes and these studies have found somewhat mixed results. Baniqued and colleagues[25] found that participants' expectations did indeed differ between training and control conditions and that this at least partially related to differences in behavior. Participants were assigned to play either a gamified cognitive training program called Mind Frontiers or a group of control activities. Following training, the participants were then asked to rate their perceived improvements in various aspects of cognition. The results showed that the Mind Frontiers group not only improved on working memory, perceptual speed, and reaction time tasks to a great degree relative to the control group, but they also expected that they would show greater improvements on average.

However, expectations have not always been seen to be linked with actual behavioral outcomes. In some cases, participants have shown expectations of improvement, but no actual improvements in cognitive skill. For instance, Guye and von Bastian[26] compared a working memory training intervention to a visual search control group. Although participants in the working memory training group indicated higher posttraining expectations of improvement compared to the visual search group, there were no actual group differences on the transfer tests (see also Souders[27]). In other cases, improvements have been seen in cognitive skills, but have been unlinked to expectations. For example, in Zhang and colleagues,[24] participants were trained on either an action video game or a control video game. In aggregate, those individuals trained on an action video game showed both greater improvements in cognitive skill and higher expectations of improvement. However, when the data were examined at the individual level, there was no relation between the individuals' degree of expectation and behavioral outcomes.

In all then, the currently available data do not point to a strong link between expectations developed during cognitive training interventions and behavioral outcomes. Yet, studies that have examined the possible influence of expectations derived during true cognitive training interventions (i.e., where the methods are typically designed to minimize differences in expectations), cannot necessarily speak to the question of whether, under some conditions, such expectation-derived improvements can exist. For this, researchers must explicitly and deliberately attempt to produce such outcomes.

Can expectation effects be induced in cognitive training?

As discussed earlier, when measured through self-report, participants' expectations do not necessarily consistently match their behavioral outcomes in cognitive training studies. However, these inferences are limited by the fact that standard cognitive training paradigms are not meant to influence participants' expectations in the first place. This has sparked interest in whether these types of effects can be induced by explicitly manipulating participants' expectations in cognitive training. There have been a variety of methods used to induce placebo effects in cognitive training, and the results—like the other work reviewed thus far—have been somewhat mixed.

At a minimum, there is reason to think that participants' beliefs about their cognitive performance are related to their behavioral performance, and more importantly, that these beliefs can easily be manipulated. For example, Green and colleagues[28] gave participants a drink that contained either glucose or aspartame and either correctly or incorrectly labeled the drink, with the idea that participants would expect that glucose has a positive effect and aspartame has no effect on cognitive performance. The glucose drink improved performance on an attentional vigilance task when participants were told that they were ingesting glucose, suggesting that at least some of the improvement in cognition was due to the participants' expectancy. Similar results have been found in other studies related to food as well (e.g., whether or not a participant believes they are ingesting caffeine).[29–30]

More specifically in the context of cognitive training, some studies have shown that participant expectations can be manipulated and that these expectations are directly related to improvements in cognitive functions. In one example, Foroughi and colleagues[31] recruited participants into a cognitive training study using two different flyers. One flyer advertised the study as a brain training and cognitive enhancement study and stated that working memory training can increase fluid intelligence, while the other flyer stated that participating in research could earn class credits. All participants then completed a single session of dual n-back training (working memory). Those who joined the study through the brain training flyer showed improvements in a fluid intelligence measure comparable to a 5-to-10-point increase on a standard IQ test after the session, while those who responded to a non-suggestive flyer showed no improvements. These results provide some evidence that participants' expectations can be manipulated, which affect subsequent cognitive outcomes. Contrary to these findings, in other studies, participants' expectations were manipulated, but were not related to any improvements in cognition. For example, Vodyanyk and colleagues[32] conducted a study in which they induced either positive or neutral expectations prior to a short session of cognitive training. They found no evidence for a placebo effect using various types of training (n-back, Tetris) in multiple domains (fluid intelligence, spatial skills).

While the aforementioned studies attempted to induce expectation-related changes in very short "training" studies (i.e., on the order of a few minutes to an hour or so), other work has examined the same question in longer cognitive training paradigms. In these studies, expectations have generally not been related to cognitive training outcomes. Using a similar flyer-recruitment method as used by Foroughi and colleagues,[31] Katz and colleagues[33] advertised a training experiment to participants that would either improve their intelligence or get paid for participating in the study. However, after completing either a dual n-back cognitive training intervention or a control knowledge-based task over the course of several weeks, the results showed no differences in improvements as a function of the expectation message. In another study, Tsai and colleagues[34] assigned participants to either a positive or negative expectation condition that received a narrated presentation about neuroscience-based "evidence" and then had them complete a week-long n-back training program or an active control activity. Overall, there were no differences in cognitive performance between the positive or negative expectation groups. Instead, the n-back group improved on an untrained working memory task while the control group showed no improvement, regardless of expectations in either training group. Similarly, Rabipour and colleagues[35] provided participants with either a positive message that cognitive training would improve their cognitive overall or a neutral message that it would not produce any benefits. They found that the expectation message had no effects on outcomes after a 5-week-long commercial cognitive training intervention called Activate.

Overall, placebo effects in the context of cognitive training seem to be nuanced, calling for further examination of the underlying mechanisms of placebo effects in cognitive training, such as when, how, and for whom they could occur.

Recommendations for future research

Now, research examining the influence of expectation effects in cognitive training interventions is limited and mixed. This is perhaps not surprising given that the research remains in its relative infancy, and, thus, there is simply not enough data to know what the central tendency in the field is, let alone how various possible mediators or moderators act in space. Available data do make several future needs quite clear.

First, there is at least sufficient evidence that expectation effects could be an issue to indicate that researchers should be as thoughtful as possible in their experimental methodology. Ideally, this should include an active control condition in addition to a passive one to match the levels of intent between conditions and to estimate possible effects in the active control.[5–6] Moreover, any active control group(s) should be closely matched to the treatment condition when possible. Compared to passive control conditions, active controls are thought to induce more similar expectations between the treatment and control participants, though they will rarely be identical expectations. In conjunction with an active control group, it would be important to get a sense of the participant's general expectations before, during, and/or after cognitive training. Questionnaires have been developed to measure exactly this purpose.[20] For example, asking participants to rate how effective they believe the cognitive training will be useful in later assessing whether expectations between conditions were similar, as well as controlling for these expectations as critical variables in statistical analyses. Yet open questions regarding such practices remain and will need careful consideration in future work (e.g., whether expectations that would not otherwise be present are created via the very act of making measurements).

Finally, while a great deal of the focus in cognitive training studies has been to minimize or eliminate expectation effects, from the perspective of real-world effects, if such effects can be induced, the opposite tactic may be preferable. For example, when examining whether cognitive skills can be improved, particularly in populations in need of cognitive improvement, rather than trying to minimize the possible effect of the participants' expectations, it may be more clinically valuable to induce and capitalize on optimistic expectations that can positively affect the outcomes of the intervention. The important outcome is seeing that cognitive skills can indeed be enhanced, whether through placebos or the intervention itself. Further, it may also be advantageous to identify which cognitive outcomes measures as well as which types of people are most susceptible to placebo effects in cognitive training. As there is evidence that cognitive training does not affect all aspects of cognition equally, there is reason to suspect placebo effects may also not be uniform across cognition. Additionally, some individual differences across participants, such as personality and motivation traits, may predict those who may be susceptible to placebo effects,[36] which in turn may be utilized to create more personalized training interventions.

In sum, it is important to understand, measure, and account for the role of participants' expectations in cognitive training. To date, there is mixed evidence whether they can account for the positive results seen from cognitive training interventions and further research is needed in this area to understand their effect sizes and how these are distributed across different types of outcome measures, differ across people, and differentially induced across manipulation types. Additionally further work would be beneficial in addressing how, in some cases, placebo effects may be of value in enhancing the real-world outcomes of cognitive training interventions.

References

1. Könen T, Strobach T, Karbach J. Working memory training. In: Strobach T, Karbach J, eds. *Cognitive Training*. Springer; 2021:155–167. http://doi:10.1007/978-3-030-39292-5_11
2. Bavelier D, Green CS. Enhancing attentional control: Lessons from action video games. *Neuron*. 2019;104(1):147–163. http://doi:10.1016/j.neuron.2019.09.031
3. Au J, Sheehan E, Tsai N, Duncan GJ, Buschkuehl M, Jaeggi SM. Improving fluid intelligence with training on working memory: A meta-analysis. *Psychonomic Bulletin & Review*. 2015;22(2):366–377. http://doi:10.3758/s13423-014-0699-x
4. Strobach T, Karbach J, eds. *Cognitive Training*. Springer; 2021. http://doi:10.1007/978-3-030-39292-5
5. Green CS, Bavelier D, Kramer AF, et al. Improving Methodological Standards in Behavioral Interventions for Cognitive Enhancement. *Journal of Cognitive Enhancement.* 2019; (3):2–29. http://doi:0.1007/s41465-018-0115-y
6. Au J, Gibson BC, Bunarjo K, Buschkuehl M, Jaeggi SM. Quantifying the difference between active and passive control groups in cognitive interventions using two meta-analytical approaches. *Journal of Cognitive Enhancement*. 2020;4(2):192–210. http://doi:10.1007/s41465-020-00164-6

7. Melby-Lervåg M, Redick TS, Hulme C. Working memory training does not improve performance on measures of intelligence or other measures of "far transfer": Evidence from a meta-analytic review. *Perspectives on Psychological Science*. 2016;11(4):512–534. http://doi:10.1177/1745691616635612
8. Simons DJ, Shoda Y, Lindsay DS. Constraints on generality (COG): A proposed addition to all empirical papers. *Perspectives on Psychological Science*. 2017;12(6):1123–1128. http://doi:10.1177/1745691617708630
9. Green CS, Bavelier D. Learning, attentional control, and action video games. *Current biology*. 2012;22(6):R197–R206. http://doi:10.1016/j.cub.2012.02.012
10. Sims VK, Mayer RE. Domain specificity of spatial expertise: The case of video game players. *Applied Cognitive Psychology*. 2002;16(1):97–115. http://doi:10.1002/acp.759
11. Hawes ZCK, Gilligan-Lee KA, Mix KS. Effects of spatial training on mathematics performance: A meta-analysis. *Developmental Psychology*. 2022;58(1):112–137. http://doi:10.1037/dev0001281
12. Ball K, Berch DB, Helmers KF, et al. Effects of cognitive training interventions with older adults: A randomized controlled trial. *JAMA: Journal of the American Medical Association*. 2002;288(18):2271–2281. http://doi:10.1001/jama.288.18.2271
13. Bediou B, Adams DM, Mayer RE, Tipton E, Green CS, Bavelier D. Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills. *Psychological Bulletin*. 2018;144(1):77–110. http://doi:10.1037/bul0000130
14. Anguera JA, Boccanfuso J, Rintoul JL, et al. Video game training enhances cognitive control in older adults. *Nature*. 2013;501(7465):97–101. http://doi:10.1038/nature12486
15. Opitz B, Schneiders JA, Krick CM, Mecklinger A. Selective transfer of visual working memory training on Chinese character learning. *Neuropsychologia*. 2014;53:1–11. http://doi:10.1016/j.neuropsychologia.2013.10.017
16. Simon SS, Tusch ES, Feng NC, Håkansson K, Mohammed AH, Daffner KR. Is computerized working memory training effective in healthy older adults? Evidence from a multisite, randomized controlled trial. *Journal of Alzheimer's Disease*. 2018;65(3):931–949. http://doi:10.3233/JAD-180455
17. Denkinger S, Spano L, Bingel U, Witt CM, Bavelier D, Green CS. Assessing the impact of expectations in cognitive training and beyond. *Journal of Cognitive Enhancement*. 2021;5:502–518. http://doi:10.1007/s41465-021-00206-7
18. Hróbjartsson A, Forfang E, Haahr MT, Als-Nielsen B, Brorson S. Blinded trials taken to the test: An analysis of randomized clinical trials that report tests for the success of blinding, *International Journal of Epidemiology*. 2007;36(3):654–663. http://doi:10.1093/ije/dym020
19. Moscucci M, Byrne L, Weintraub M, Cox C. Blinding, unblinding, and the placebo effect: An analysis of patients' guesses of treatment assignment in a double-blind clinical trial. *Clinical Pharmacology and Therapeutics*. 1987;41(3):259–265. http://doi:10.1038/clpt.1987.26
20. Rabipour S, Davidson PSR. Do you believe in brain training? A questionnaire about expectations of computerised cognitive training. *Behavioural Brain Research*. 2015;295:64–70. http://doi:10.1016/j.bbr.2015.01.002
21. Hynes S. Internet, home-based cognitive and strategy training with older adults: A study to assess gains to daily life. *Aging Clinical & Experimental Research*. 2016;28(5):1003–1008. http://doi:10.1007/s40520-015-0496-z
22. Yeo SN, Lee TS, Sng WT, et al. Effectiveness of a personalized brain-computer interface system for cognitive training in healthy elderly: A randomized controlled trial. *Journal of Alzheimer's Disease*. 2018;66(1):127–138. http://doi:10.3233/JAD-180450
23. Boot WR, Simons DJ, Stothart C, Stutts C. The pervasive problem with placebos in psychology: Why active control groups are not sufficient to rule out placebo effects. *Perspectives on Psychological Science*. 2013;8(4):445–454. http://doi:10.1177/1745691613491271

24. Zhang R-Y, Chopin A, Shibata K, et al. Action video game play facilitates "learning to learn." *Communications Biology*. 2021;4(1):1154. http://doi:10.1038/s42003-021-02652-7
25. Baniqued PL, Allen CM, Kranz MB, et al. Working memory, reasoning, and task switching training: transfer effects, limitations, and great expectations? *PLoS ONE*. 2015;10(11):e0142169. http://doi:10.1371/journal.pone.0142169
26. Guye S, von Bastian CC. Working memory training in older adults: Bayesian evidence supporting the absence of transfer. *Psychology and Aging*. 2017;32(8):732–746. http://doi:10.1037/pag0000206
27. Souders DJ, Boot WR, Blocker K, Vitale T, Roque NA, Charness N. Evidence for narrow transfer after short-term cognitive training in older adults. *Frontiers in Aging Neuroscience*. 2017;9:41. http://doi:10.3389/fnagi.2017.00041
28. Green MW, Taylor MA, Elliman NA, Rhodes O. Placebo expectancy effects in the relationship between glucose and cognition. *British Journal of Nutrition*. 2001;86(2):173–179. http://doi:10.1079/bjn2001398
29. Fillmore MT, Mulvihill LE, Vogel-Sprott M. The expected drug and its expected effect interact to determine placebo responses to alcohol and caffeine. *Psychopharmacology*. 1994;115(3):383–388. http://doi:10.1007/BF02245081
30. Fillmore M, Vogel-Sprott M. Expected effect of caffeine on motor performance predicts the type of response to placebo. *Psychopharmacology*. 1992;106(2):209–214. http://doi:10.1007/BF02801974
31. Foroughi CK, Monfort SS, Paczynski M, McKnight PE, Greenwood PM. Placebo effects in cognitive training. *PNAS*. 2016;113(27):7470–7474. http://doi:10.1073/pnas.1601243113
32. Vodyanyk M, Cochrane A, Corriveau, A, Demko Z, Green CS. No evidence for expectation effects in cognitive training tasks. *Journal of Cognitive Enhancement*. 2021;5:296–310. http://doi:10.1007/s41465-021-00207-6
33. Katz B, Jaeggi SM, Buschkuehl M, Shah P, Jonides J. The effect of monetary compensation on cognitive training outcomes. *Learning and Motivation*. 2018;63:77–90. http://doi:10.1016/j.lmot.2017.12.002
34. Tsai N, Buschkuehl M, Kamarsu S, Shah P, Jonides J, Jaeggi SM. (Un)great expectations: The role of placebo effects in cognitive training. *Journal of Applied Research in Memory and Cognition*. 2018;7(4):564–573. http://doi:10.1037/h0101826
35. Rabipour S, Morrison C, Crompton J, et al. Few effects of a 5-week adaptive computerized cognitive training program in healthy older adults. *Journal of Cognitive Enhancement*. 2020;4:258–273. http://doi:10.1007/s41465-019-00147-2
36. Geers AL, Helfer SG, Kosbab K, Weiland PE, Landry SJ. Reconsidering the role of personality in placebo effects: Dispositional optimism, situational expectations, and the placebo response. *Journal of Psychosomatic Research*. 2005;58(2):121–127. http://doi:10.1016/j.jpsychores.2004.08.011