Are Cognitive Training Effects on Fluid Intelligence Simply Expectancy Effects?

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Abstract

A recent study on placebo effects in cognitive training showed significant gains from pretest to posttest, however the study had a self-selection bias resulting in heterogeneous samples. The placebo group included significantly more individuals with a growth mindset. I aimed to examine if these differences would still be found if participants were randomly assigned to conditions. My hypothesis was that Participants in the expectancy condition would score higher on the posttest than those in the control condition. Additionally I hypothesized that those in the expectancy condition with growth mindsets would score higher than those with fixed mindsets. The expectancy condition was verbally primed to expect that a short cognitive training (n-back) would improve their scores on the posttest measure of fluid intelligence. The control condition did not receive any priming. No significant differences were found between the two conditions, however the expectancy condition did score higher on the posttest. Additionally within the expectancy condition the participants with growth mindsets scored higher than those with fixed mindsets. The results, paired with previous research point to the possibility of a weak relationship between growth mindsets and an increased susceptibility to the placebo effect in relation to cognition.

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Raymond Cattell is credited with coining the terms fluid and crystalized intelligence (Brown, 2016). Firm cemented knowledge is referred to as crystalized intelligence whereas the ability to solve novel problems is referred to as fluid intelligence. Fluid intelligence has been an area of interest for a long time because it represents the dynamic problem solving ability that seems so unique to humans. The desire to increase this form of intelligence has created the booming new industry of cognitive training.

Recently, many brain training websites and apps have launched with promises to improve different areas of cognition (The Science Behind NeuroNation. n.d.; Lumosity's Human Cognition Project: A collaborative effort to accelerate cognitive research n.d.). There is currently conflicting evidence concerning the efficacy of cognitive training. Recent studies on cognitive training have happened in several areas.

Age has been found to be a significant factor: young children age 4-6 in china showed increases in fluid intelligence after repeated n-back trials as compared to a control group (Peng, Mo, Huang, Zhou, 2017). The n-back task involves a continuing stream of images that appear one by one on the screen. The participant must indicate whether the picture on the screen is the same as it was "n-back" in the sequence. The improvement in fluid intelligence persisted at six, and twelve-month follow-up tests. The sample of children was relatively small but these findings are impressive. One possible explanation for the enhanced effect found in young children is that n-back training encourages children to invent new mental strategies for memorization. This is because the task forces you to continually update what are in your working memory. This effect may not be as pronounced in adults because mental strategies become more cemented as we age. Another factor that is not mentioned by Peng et al. is that some evidence has indicated that the placebo effect is stronger in children (Schlarb, Schwille-Kiuntke, Weimer, Gulewitsch, Enck, & Klosterhalfen, 2013). These findings from children are encouraging. Similar studies have been done with elderly populations suffering from cognitive impairments with the hopes of similar results. Unfortunately the same robust effects have not yet been found.

Stroke patients showed some improvements but the results are muddy (Ven, Murre, Veltman, & Schmand, 2016). Some stroke patients showed improvements on posttests but how much of that was due to the brain training isn't clear. Whether or not the effects from the training generalize to tasks other than the brain training itself is also unclear. Most of the studies done with stroke patients had extremely small sample sizes. It is difficult to tease apart what gains are due to natural healing after the stroke versus the training itself. I have outlined how age can play a role in the effects of cognitive training. There have also been studies with healthy young adults.

College students that went through one month of n-back training showed improvements in fluid intelligence (Jaeggi, Studer-Luethi, Buschkuehl, Yi-Fen, Jonides, & Perrig, 2010). There were significant gains in fluid intelligence using two separate matrix measures. The participants were separated into three groups. They performed single n-back, dual n-back or were in a no-contact control group. Dual n-back is more complex as it involves both the normal n-back procedure as well as matching the location of the image in a particular quadrant of the screen. It was found that single n-back showed larger improvements in fluid intelligence than the dual n-back. The control condition also performed the n-back training without researcher involvement. All three groups showed improvements in fluid intelligence however, the effect was stronger for the non-control conditions. This highlights the role of motivation in cognitive training. Both the single n-back and the dual n-back groups met in a computer lab and worked while a researcher was in the room. This may have forced them to pay more attention to the task. The authors did not mention how they framed the task to participants. Did they call it cognitive training? If so this may have primed participants to expect that they would improve their cognition. Recently the role of placebo effects and mindset has been explored in relation to cognitive training.

The placebo effect is a well-established concept in psychological and medical research. Early in medical research the placebo effect was thought to only apply to pain (Peciña, Stohler, & Zubieta, 2014). In the decades that followed the true scope of this phenomenon has born out. Placebo effects in relation to antidepressant drugs have shown that symptoms of depression can be reduced even though the participant is only taking a sugar pill (Schalkwijk, Undurraga, Tondo, & Baldessarini, 2014). Recently DNA testing was shown to have a placebo effect (Turnwald, Goyer, Boles, Silder, Delp & Crum, 2018). In the former study participants were given fake DNA test results that told them they were either at risk, or protected from, obesity or lowered endurance. The researchers first gathered baseline data on satiety and endurance. After receiving the phony results they were tested again and the results showed both cognitive and physiological changes in the participants that related to their phony results. In other words if the participant thought they were at risk for obesity they reported feeling less satiated after a meal and had lower levels of the hormones associated with satiety. The scope of the placebo effect seems to be ever increasing and there is no reason that it should not apply to cognition as well.

Recently placebo effects in relation to cognitive training were found (Foroughi, Monfort, Paczynski, McKnight, & Greenwood, 2016). Unfortunately this study lacked random assignment to conditions. The authors recruited participants using two different posters, one advertised a study on brain training that included a claim that cognitive training has been shown to improve fluid intelligence. The other poster simply advertised a study and gave no information about brain training. This study showed that those in the placebo group (recruited through the brain training poster) showed significant improvement from pretest to posttest. Where as the control group did not show improvement. The authors had participants complete two different tests of intelligence, the BOMAT and the Raven's progressive matrix to gather a baseline followed by one hour of n-back training. The following day, participants came back and completed the BOMAT and Raven's again. The authors included the theories of intelligence scale and found significantly higher beliefs in the malleability of intelligence in the placebo group. This highlights their self-selection bias. This begs the question, what types of people are drawn to cognitive training?

Many people who are drawn to cognitive training may be motivated individuals who are expecting to increase their cognition. The importance of expectancy effects should not be overlooked. Individuals as a whole who participate in cognitive training might have a propensity toward a growth mindset. Growth mindsets are categorized by the individual belief that intelligence can be increased through effort (Dweck, 2017). It may be that people with growth mindsets respond to cognitive training better because of an enhanced placebo effect in relation to cognition.

To adapt the study by Foroughi et al., I investigated expectancy effects and brain training but used random assignment of conditions. One group was told, "this brain training has been shown to increase fluid intelligence." The other group was told nothing other than explaining the procedure. My hypothesis is that participants in the condition that is primed with an expectancy cue will score higher on measures of fluid intelligence. Additionally I hypothesize that those with growth mindsets will show greater improvements on the posttest than those with fixed mindsets. I utilized the Raven's progressive matrices 2. The Raven's matrices tests were developed in the 1940s. They were designed to be a nonverbal measure of intelligence as opposed to IQ tests that rely heavily on verbal and language intelligence. Since then, they have been used in countless studies and remain a widely used test of fluid intelligence (Raven, 2003; "Raven's Progressive Matrices," n.d.; Brown, 2016). The Raven's 2 is a new digital adaptation of the original raven's test. The digital adaptation of the Raven's 2 made it possible to gather data in group-sessions. The BOMAT was not used because of monetary constraints. To assess mindset I used the Implicit Theories Of Intelligence scale (ITIS). The ITIS was developed by Carol Dweck and has shown good reliability with Cronbach's alpha of .81-.87 (Castella, & Byrne, 2015; Schiano-Lomoriello, Cury, Poinso, Rufo, & Therme, 2007). The ITIS measures participants mindset's toward intelligence and to what degree the participant thinks intelligence is fixed.

To assess how much attention participants were paying to the n-back task a score for d' was calculated. The d' statistic comes from signal detection theory. It is calculated with a ratio of false alarms and hit rates (Signal Detection: D' Defined, n.d.). A minimum d' of 2 was needed to be included in the data analysis.

Method

Participants

Participants were recruited through the online SONA system used in the department of Psychology for student research participation. Participants were CSU Chico students taking at least one psychology course. Sessions of up to eight participants at a time were conducted in a computer lab in our department.

Materials

The Ravens progressive matrix 2 was used to assess fluid intelligence. A single n-back task built by Dr. Martin Van den Berg was used as the cognitive training. It included 12 different images of common cartoon characters. Participants did not move beyond 2-back. A d' score was calculated from the n-back task. The Theories of Intelligence scale was used to assess mindset.

Procedure

Data collection required two consecutive days. The first day, participants arrived and were given the informed consent to read and sign. Then, using a separate computer, each participant completed the online short form of the "Raven's Progressive Matrices 2" to gather a baseline of fluid intelligence. The n-back task was explained and participants completed a 20-minute n-back training session.

The next day, participants completed the online long form of the Raven's 2, and the Dweck Theories of Intelligence scale. After everyone finished, participants were debriefed and thanked for their participation.

There are two conditions: the expectancy condition and the control condition. The expectancy condition was told aloud that the 20-minute n-back training has been shown to increase cognitive ability, specifically fluid intelligence as measured by the Raven's test. This message is consistent with the claims of many cognitive training websites. In the control condition there was no mention of a connection between n-back training and fluid intelligence.

The PI conducted every session using the same script to keep instructions consistent. Lab sessions were randomly assigned ahead of time as either expectancy or control. Participants signed up for a time that works for their schedule, not knowing what condition the session was. It took 34 sessions to gather an adequate amount of data.

Results

A final sample of 57 participants was gathered for analysis. The sample was predominantly female 81%, ages ranged from 18-49 (M = 23). All participants met the minimum d' requirement of 2 or better. The data was analyzed with a 2 (condition: expectancy, control) x 2(mindset: fixed, growth) ANCOVA controlling for the pretest and d'. No significant main effects or interactions were found. However, the means of the posttest scores on the Raven's 2 were in the predicted direction showing that the expectancy condition (M = 102.63) did score higher than the control condition (M = 99.45) see figure 1. There was a significant correlation between d' scores and Post test scores on the Raven's 2, $r(55) = .47$, $p < .001$. The correlation between d' and the posttest scores was examined separately for the control and the expectancy conditions. The expectancy condition had a moderate to strong correlation between posttest scores and d', $r(28) = .39$, $p = .035$. The control condition also had a significant strong correlation between posttest scores and d', $r(22) = .64$, $p = .001$. These two correlations were not significantly different from each other.

Discussion

One possible reason for the non-significant results may have been the relatively small sample size. The effect size is small and larger samples may be needed to see significant differences between groups. It is also possible that there are no placebo effects in cognitive training. Interestingly how much attention the participants paid to the n-back training (d') did have a relationship to how well they did on the Raven's. This could reflect personal differences in attentional capacity. Participants who devoted considerable attention to the n-back task may have also paid closer attention to the Raven's. The strong association between d' and raven's scores may suggest that d' is a fairly good predictor of fluid intelligence.

When the correlation between d' and posttest scores were examined separately for the expectancy and control I was surprised to find that the correlation was stronger for those in the control group. The only difference between the two groups was the verbal instructions in the expectancy condition that told the participants that the n-back training would improve their scores on the Raven's posttest. It is unclear whether the verbal priming in the expectancy group caused those participants to put in less effort. It is possible that being told the n-back would help, made participants take a more passive role during the n-back training.

I chose to make the n-back training shorter than in the study by Foroughi et al. out of a desire to reduce the time commitment of participants and reduce fatigue. The n-back training was not meant to actually improve scores and was essentially a distractor task. N-back training done through cognitive training websites is completed over a series of weeks or months. There is no research showing that one short exposure to n-back training would create any actual change in fluid intelligence. Therefore shortening the time of the training was not seen as a problem because it makes the possibility of actually changing fluid intelligence even more remote. It is possible that the longer duration of training could have been more convincing to participants and increased the placebo effect.

The results of this study show that the differences shown by Foroughi et al. were likely due to the self-selection bias. They had heterogeneous samples where the placebo group had significantly higher levels of growth mindsets. My data showed that participants in the expectancy condition who had growth mindsets did score higher on the posttest though not statistically higher. This difference is interesting because it may indicate that those with growth mindsets are more susceptible to placebo effects in relation to cognition. This conclusion makes theoretical sense because people with fixed mindsets do not believe that intelligence is malleable therefore would be less likely to believe that their own intelligence would be improved.

Future research should continue to investigate the relationship between cognitive training and fluid intelligence. However, more attention should be paid to how participants are recruited and what preconceived notions they have about cognitive training. Another key aspect to cognitive training that needs to be explored further is motivation and attention. The strong relationship between d’ and fluid intelligence shows that attentional capacity and motivation may play a much larger role in the gains from cognitive training than previously thought.

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Figures

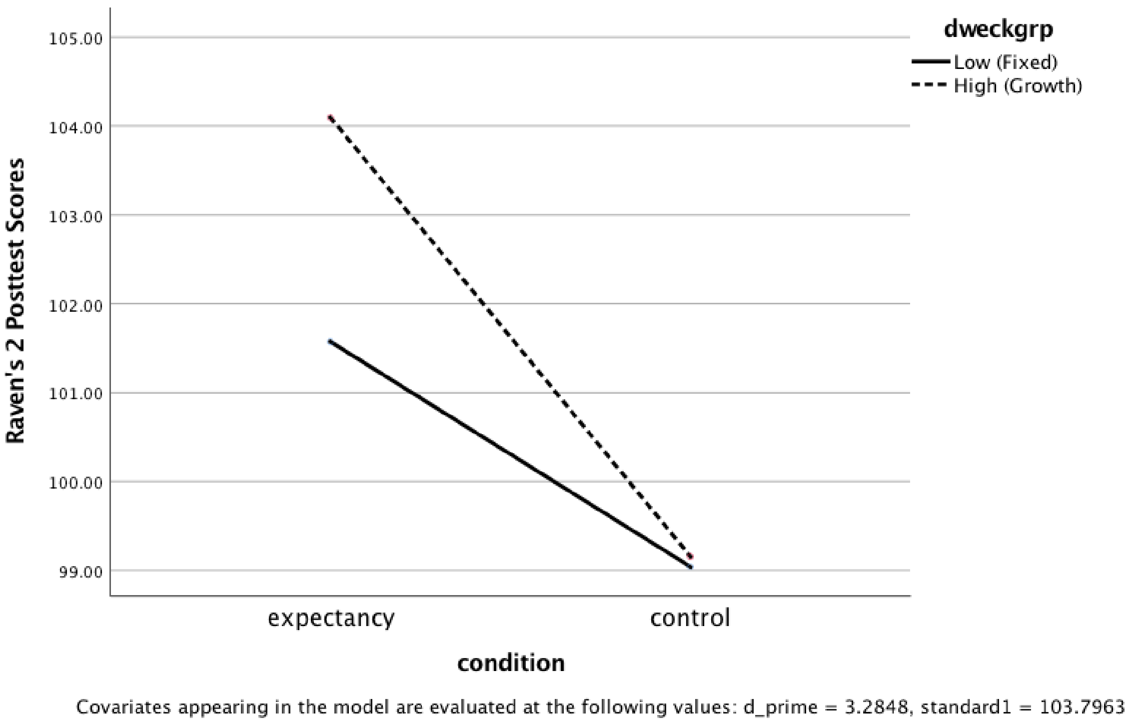

Figure 1. Covariate adjusted means for the posttest scores of the Raven's 2 measuring fluid intelligence

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