In press at American Psychologist

How Malleable Are Cognitive Abilities?
A Critical Perspective on Popular Brief Interventions

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Acknowledgments

I would like to thank Andrew Conway, Michael Corballis, and Michael Kane for helpful comments on an earlier version of this manuscript. This work was supported by a Marsden grant from the Royal Society of New Zealand, funding from the Neurological Foundation of New Zealand, and an Early Career Research Award (ECREA) from The University of Auckland.

Abstract

A number of popular research areas suggest that cognitive performance can be manipulated via relatively brief interventions. These findings have generated a lot of traction, given their inherent appeal to individuals and society. However, recent evidence indicates that cognitive abilities might not be as malleable as preliminary findings implied, and that other, more stable factors play an important role. Here, I provide a critical outlook on these trends of research, combining findings that have mainly remained segregated despite shared characteristics. Specifically, I suggest that the purported cognitive improvements elicited by many interventions are not reliable, and that their ecological validity remains limited. I conclude with a call for constructive skepticism when evaluating claims of generalized cognitive improvements following brief interventions.

Keywords: environment; behavioral interventions; cognitive improvements; brain plasticity; genetics; intelligence

Public Significance Statement

This review discusses evidence across a number of popular brief interventions designed to enhance cognitive abilities, and suggests that these interventions often fail to elicit reliable improvements. Consequences of exaggerated claims are discussed, together with a call for constructive criticism when evaluating this body of research.

People differ in a number of ways, including cognitively—some individuals appear to retain and synthesize knowledge effortlessly, whereas others show difficulties learning basic concepts (Hunt et al., 1973). These differences in intrinsic ability or aptitudes have been related to differences in life outcomes, for example within academic and professional contexts (Brody, 1997), and an extensive literature has demonstrated the relative stability of individual differences across the lifespan (Deary et al., 2000, 2012; Featherman et al., 2019). Recently, this notion has been challenged with a number of research areas centered on a common rationale: aptitudes, abilities or performance can be greatly improved with relatively brief, simple manipulations or interventions. For example, **mindset** interventions (for definitions of the words in boldface type, see Table 1) lasting for as little as an hour have been associated with myriad benefits, including better learning (Xu et al., 2020), enhanced problem-solving skills (Mueller & Dweck, 1998), and greater academic achievement (Paunesku et al., 2015; Walton & Wilson, 2018; Yeager et al., 2019). Similarly, **stereotype threat** research indicates that performance on a range of tasks is remarkably susceptible to individual beliefs about group performance—if primed with a reminder that they belong to a particular group known to typically perform poorly on a test or task, individuals' performance will tend to worsen, whereas subtle manipulations suggesting that one's group typically performs better than or as well as others can sometimes completely erase pre-existing differences (C. M. Steele & Aronson, 1995). Although these interventions target beliefs about ability rather than the abilities themselves, other types of regimens, typically spanning a few weeks or months, have shown similar improvements with a direct focus on intrinsic abilities. Findings in the field of **brain training** suggest that cognitive abilities can be improved via targeted training, either focused on a single modality (e.g., working memory training; Jaeggi et al., 2008; Klingberg et al., 2005; Loosli et al., 2012), or using a range of brain exercises tapping into various abilities (see Simons et al., 2016, for an extensive review), whereas research on **video gaming** has purportedly shown that beyond being fun and engaging, commercial video games can also elicit cognitive improvements that generalize to other tasks and contexts (Box 1; Green & Bavelier, 2003, 2007).

Table 1. Glossary

Term	Definition
Brain plasticity	The brain's ability to modify itself to adapt to its environment. Also referred to as 'neuroplasticity', brain plasticity is an umbrella term that encompasses a variety of neurobiological processes, including—but not limited to—neurogenesis (the creation of new neurons) and synaptogenesis (the creation of new synapses).
Brain training	A regimen purported to enhance cognitive ability in a non-transient way, via a single (or a set of) cognitive task(s). The terms 'brain training' and 'cognitive training' are usually used interchangeably, whereas more specific terms such as 'working memory training' or 'perceptual training' refer to brain training regimens that focus on single abilities.
Cognitive improvement	A gain in cognitive performance elicited by an intervention or a training regimen.
Cognitive intervention	A behavioral intervention intended to affect cognitive abilities or cognitive performance, either directly (e.g., cognitive training) or indirectly (e.g., by intervening on beliefs or contextual cues). Cognitive interventions are typically associated with claims of transfer (see below). The focus of this paper is on brief interventions—interventions that last a short amount of time, typically with a single (e.g., stereotype threat) or relatively few sessions (e.g., mindset). Although some of the interventions discussed herein can be deployed over longer periods of time (e.g., brain training, video gaming), they were nonetheless included as numerous claims have been made about their impact on cognitive performance following a small number of sessions (see main text for references).
Cognitive malleability	The capacity for our cognitive abilities to change and adapt as a result of experience (e.g., education, training, intervention) in a measurable, meaningful way. Change should typically be measured at the level of latent (unobserved) construct, rather than at the level of single cognitive tasks.

Cognitive remediation	The use of a cognitive intervention to alleviate a mental health or neurological condition (e.g., ADHD, Alzheimer's disease).
Genetic essentialism	The reductionist view that human characteristics and behaviors are essentially based on their perceived genetic make-up.
Hawthorne effect	The alteration of behavior in study participants in response to their awareness of being observed.
Just-world fallacy	The false assumption that all individual actions have fair and just consequences. The fallacy is perhaps best illustrated by the saying "what goes around, comes around".
Matthew effect	A social phenomenon describing the accumulation of advantages or disadvantages, often summarized by the adage "the rich get richer and the poor get poorer".
Mindset	A set of assumptions or beliefs about the malleability of human aptitudes. According to mindset theory, some individuals believe that aptitudes are mostly immutable (fixed mindset), whereas others view aptitudes as mostly malleable (growth mindset). Proponents of the theory have suggested that the latter group enjoy far superior outcomes in a variety of settings, including academic and professional, and that mindsets themselves are malleable, demonstrated via brief interventions.
Opportunity costs	The loss of potential gain from other alternatives when one alternative is selected.
Stereotype threat	The risk of confirming negative stereotypes about one's racial, gender, cultural, or social group.
Transfer	Following an intervention, generalized improvements beyond the context of the intervention itself. Researchers typically distinguish between near and far transfer; see Box 1 for details.
Video gaming	In this context, playing video games to elicit generalized cognitive improvements, that is, improvements that transfer beyond the context of the video game itself (see also Box 1).

INSERT BOX 1 ABOUT HERE

The general notion that brief, relatively straightforward **cognitive interventions** can profoundly influence individual performance on a variety of cognitive tasks and academic assessments has also gained popularity outside of scientific circles, finding its way into school curricula and policies[1]. Popular books depicting stories of individuals who have changed their brains in remarkable ways have filled bookshelves (Doidge, 2007; Dweck, 2008; Hurley, 2014); online talks on the same topics can often reach millions of viewers. Yet the aforementioned research areas have also made the headlines for another reason: all have been questioned by a number of studies, either failed replications (Bahník & Vranka, 2017; Flore et al., 2018; Foliano et al., 2019; Harrison et al., 2013; Murphy & Spencer, 2009; Redick et al., 2013; Stricker & Ward, 2004; van Ravenzwaaij et al., 2014) or large meta-analyses (Melby-Lervåg et al., 2016; Sala et al., 2018; Sisk et al., 2018; Stoet & Geary, 2012). Meta-analytic estimates further indicate that true heterogeneity in the cognitive-intervention literature is either null or extremely slim, and centers on null effects, suggesting an overall lack of effectiveness (Aksayli et al., 2019; Gobet & Sala, 2020; Melby-Lervåg et al., 2016; Sala et al., 2019; Sisk et al., 2018). Although these mixed findings might not question the validity of each line of research *per se*, they underline important gaps in our theoretical understanding of **cognitive malleability** and its determinants (Moreau, 2021).

Admittedly, the aforementioned research areas are not the only mainstream cognitive interventions that have come under scrutiny in the last few years. For example, areas such as bilingualism (Lehtonen et al., 2018), chess playing (Sala & Gobet, 2017), music training (Sala & Gobet, 2017, 2020b), and physical exercise (Diamond & Ling, 2019b) have all been called into question by recent meta-analytic findings. Yet these activities are associated with a number of benefits that are not contingent upon cognitive gains—from mastering another language, the game of chess, or a musical instrument, to staying fit and healthy. In contrast, the motivation to participate in brain training, stereotype threat, mindset, or (perhaps to a lesser extent) video game interventions largely depends on the scientific evidence for

[1] See for example this announcement from the United States Department of Education in support of Mindset programs in schools: https://www.ed.gov/news/press-releases/us-department-education-announces-first-ever-skills-success-grants-and-initiative-support-learning-mindsets-and-skills

cognitive gains (Moreau, 2021). As such, reliable assessment of empirical claims, together with a finer understanding of the underlying mechanisms, is arguably more pressing for the four areas of research discussed herein than for activities intrinsically associated with positive outcomes. Building on these four examples, here I revisit evidence for the notion that brief cognitive interventions can elicit meaningful, generalized cognitive improvements, and suggest that many popular findings are inconsistent with dominant theoretical and empirical frameworks in psychology and neuroscience.

Mechanisms and Limits of Cognitive Improvement

Although cognitive improvements are changes that are measured, and thus defined, at the behavioral level, proponents of cognitive interventions often embrace a rhetoric rooted in neuroscience to justify claims of improvements. Specifically, one key account to explain generalized improvements following cognitive interventions is that of **brain plasticity**. In her bestseller *Mindset* (Dweck, 2008), Carol Dweck describes a typical growth mindset intervention in which researchers tell students how "the brain is more like a muscle [...] (it) grows and gets stronger when you learn" (p. 229). In a related TED talk[2], Dweck specifically mentions how 'fixed mindset' students show "hardly any (brain) activity" when confronted with a problem, in contrast with 'growth mindset' students, whose "brain is on fire" when facing the same challenges. This is not just a peculiarity of popular media—similar claims, reviewed in a recent publication by Burgoyne and colleagues (2020), have been made in peer-reviewed publications (e.g., Dweck, 2012).

Relatedly, many brain training programs claim to be based on what is often referred to as the "new science of brain plasticity" (Merzenich, 2013), and use this rhetoric to support claims of improvement. Examples abound, but this is perhaps most evident in the context of **cognitive remediation**: "given the great weight of evidence for neuroplasticity, why are cognitive exercises not more widely recognized as a treatment for learning disabilities?" (Arrowsmith-Young, 2012). Similar arguments have been made in video gaming research (Bavelier & Davidson, 2013), especially when emphasizing potential for low-performing individuals. Skeptics are told that the idea that the brain is fixed has long been debunked (Tokuhama-Espinosa, 2018), and that any reluctance to accept findings touting intervention-induced cognitive improvements is thus misguided (Arrowsmith-Young, 2012).

[2] https://www.ted.com/talks/carol_dweck_the_power_of_believing_that_you_can_improve

There are several issues with this rhetoric. First, calling upon the plastic properties of the brain neither validates nor undermines claims of improvement. Learning *is* undoubtedly associated with neural changes, both at the functional (Woollett & Maguire, 2011) and structural levels (Scholz et al., 2009; C. J. Steele et al., 2013). Whether learning generalizes across stimuli, tasks, or contexts, however, is another matter altogether. Furthermore, the commonly emphasized novel aspect of brain plasticity is also unwarranted. Neural processes supporting learning, such as synaptogenesis and long-term potentiation, have been documented for decades (Bliss & Lømo, 1973; Sperry, 1963); adult neurogenesis was first demonstrated more than half a century ago (Altman, 1962; Altman & Das, 1965). This field of research remains extremely active; for example, the jury is still out with respect to whether adult neurogenesis occurs at all in humans (Anacker et al., 2018; Moreno-Jiménez et al., 2019; Sorrells et al., 2018). Yet these claims have little relevance to the notion of intervention-induced cognitive improvements—even interventions that fail to elicit changes at the level of cognitive constructs are associated with neural changes (Román et al., 2016).

Shifting focus to behavior does not eliminate all inconsistencies. The core idea of all these research areas is that the ability or mechanism being targeted by the intervention is central to many aspects of performance (Melby-Lervåg et al., 2016; Sala et al., 2018; Sisk et al., 2018; Stoet & Geary, 2012), and thus has downstream ramifications to many aspects of our lives. Yet many questions remain. For example, given the width of experiences to which individuals are exposed daily, how can interventions that appear to largely mirror natural environments elicit substantial change? Or, put differently, what is so special about these interventions that leads to improvements, above and beyond everyday interactions within ecological settings? This is perhaps most explicit in the case of mindset interventions, where experimental manipulations are very similar to the type of feedback students have typically received at school and at home for years, sometimes decades (Song, 2018; Sun, 2019; Truax, 2018). Despite these similarities, natural feedback appears to have no clear effect—mindset is not associated with academic persistence (Macnamara & Rupani, 2017), and correlates at best weakly with achievement or performance in ecological settings (Sisk et al., 2018)—whereas growth mindset feedback delivered over a session or two has measurable consequences (Paunesku et al., 2015; Yeager et al., 2019). Similar arguments hold for stereotype threat research, brain training, and video gaming—how can interventions whose characteristics do not appear to drastically differ from natural environments have such profound impact?

Intervention proponents have attempted to address this criticism, for example via the notion of “recursive processes that accumulate effects over time” (Yeager & Walton, 2011; p. 285) in mindset research. The rationale with this argument is that although mindset interventions are brief, they help initiate what can be conceptualized as a ‘snowball effect’, “whereby better performance each term reinforce[s] more adaptive attributions for early academic struggles” (Yeager & Walton, 2011; p. 277). In the same paper, Yeager and Walton (2011) also discuss this idea in the context of stereotype threat interventions, whereas a similar rationale has been proposed in the field of brain training, especially in developing populations—although training is brief and targeted, it is thought to enable more engagement with the natural classroom environment, so that the latter itself becomes a form of training (see Sala & Gobet, 2020a, for a recent review). These are laudable attempts to uncover some of the mechanisms underlying cognitive interventions, and represent developments in the right direction. However, it remains that the aforementioned inconsistencies are not well explained by current, poorly defined frameworks of cognitive malleability (Katz et al., 2018; Renshaw et al., 2018), and underline the lack of theoretical grounds within these research areas (Katz et al., 2018).

Toward Nuanced Claims of Improvement

It could be argued that in the case of interventions, mechanisms do not matter, as effects themselves have inherent implications. Why worry about underlying mechanisms when an intervention shows tangible benefits? This view, however, is problematic for a number of reasons. First, it prevents generalizations to individuals who differ from typical research participants (i.e., out-of-sample predictions). For example, in some contexts low-performing individuals appear to benefit most from brain training interventions (Jaeggi et al., 2008; Zinke et al., 2014); in others, individuals with higher baseline performance seem to show greater improvements (Bürki et al., 2014; J. L. Foster et al., 2017; Guye et al., 2017). Similarly, a number of mindset interventions have shown greater benefits for individuals with lower socioeconomic status (Paunesku et al., 2015; Yeager et al., 2019), whereas others have not (Brez et al., 2020; Burgoyne et al., 2018). Why these effects differ across studies remains largely unknown, hindering robust predictions in a variety of contexts (Cesario, 2014).

Second, poor understanding of the mechanisms of improvement exacerbates threats to construct validity: if interventions are associated with other, unidentified variables that are not directly manipulated, or if the manipulated variables have consequences unbeknownst to the researcher on other factors, the hypothesized improvements might not hold outside of research settings. For example, a cognitive intervention may be systematically associated with specific characteristics (researchers, environments, protocols) that are part of the original study, but not of scaled implementations. This is not unreasonable given that cognitive-intervention studies are almost never double-blind (Moreau & Corballis, 2019), and thus that participants' or researchers' expectations have the potential to influence study outcomes (see Box 2). Importantly, random assignment to experimental conditions does not necessarily circumvent this limitation, especially when confounds are subtle and theoretical frameworks undefined.

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Finally, limited theoretical frameworks of cognitive malleability also preclude convincing claims for gains at the latent level, as opposed to the more plausible artificial improvements on a task or set of tasks (Moreau & Conway, 2014; Moreau & Wiebels, 2021; Shipstead et al., 2012). Improvement is often demonstrated at the level of a single task, thought to measure the latent ability of interest (but see for instance Paunesku et al., 2015; Yeager et al., 2019, for counterexamples), despite empirical work demonstrating that task improvements and change in latent ability are not synonymous (Moreau et al., 2016; Shipstead et al., 2012), especially in the context of interventions (Moreau & Conway, 2014). Single tasks can be very sensitive to similarities with training regimens, or more broadly be impacted by a component of the intervention despite the absence of change in latent ability (Sala & Gobet, 2019; Shipstead et al., 2012; Simons et al., 2016). When cognitive interventions include multiple outcome measures of the underlying construct, claims of improvement are much more elusive or limited (Colom et al., 2013; Foliano et al., 2019; Harrison et al., 2013; Owen et al., 2010; Redick et al., 2013; Stojanoski et al., 2020; Unsworth et al., 2015).

In accounting for these limitations, proponents of cognitive interventions are revisiting strong, early claims with more nuanced statements. From the "striking effects on educational achievement" of mindset interventions (Yeager & Walton, 2011), "striking differences in the pattern of performance" between growth- and fixed mindset students (Diener & Dweck, 1978), or "the striking result of a training-related gain in fluid intelligence" (Jaeggi et al., 2008), the discourse in the same research groups now favors more measured statements. Caution with respect to the meaning of cognitive gains at the construct level (e.g., "the main finding showed no significant changes in the assessed psychological constructs"; Colom et al., 2013), or about unwarranted generalizations (e.g., "not all forms of growth mindset interventions can be expected to increase grades, even in the targeted subgroups"; Yeager et al., 2019; Box 3) is now common. This apparent shift to reconcile bold early rhetoric with subsequent null findings in large replications (Foliano et al., 2019; Redick et al., 2013) is consistent with recent developments in a broader line of work in the behavioral sciences, which have challenged the idea that behavior is highly malleable and can be easily molded via experimental manipulations (Moreau et al., 2019). Can a few minutes spent with our feet apart, hands on hips and chin upward help us secure our dream job at the next interview (Carney et al., 2010)? Can holding a pen between our teeth let us see life in a more cheerful way (Strack et al., 1988)? Or does reading words commonly associated with the elderly make us walk slower (Bargh et al., 1996)? Based on well-powered—often preregistered—failed replications (Acosta et al., 2016; Doyen et al., 2012; Garrison et al., 2016), the answer to all of the above appears to be negative, casting further doubt on extreme stances about the malleability of behavior.

INSERT BOX 3 ABOUT HERE

These inconsistent findings do not necessarily mean that generalized cognitive improvements are impossible (but see Sala & Gobet, 2017, 2019), yet it does suggest that meaningful gains remain elusive and restricted (Diamond & Ling, 2019a; Harrison et al., 2013; Meiran et al., 2019; Simons et al., 2016; Takacs & Kassai, 2019), with heavily constraining individual baselines (Guye et al., 2017; Zinke et al., 2014), and that little is known about how individual characteristics influence long-term changes in cognitive ability (Bailey et al., 2020; Bunge & Wright, 2007). Cognitive improvements are likely more dynamic than commonly acknowledged in the intervention literature mentioned herein—when genuine, gains are typically short-lived (Jaeggi et al., 2014; Orosz et al., 2017), often have limited ecological validity (Harrison et al., 2013; Moreau & Conway, 2014; Shipstead et al., 2012), and are most plausibly constrained by attractor states within nonlinear dynamical systems (McClelland et al., 2010; Renshaw et al., 2018; Taya et al., 2015). In addition, reciprocal relationships between cognitive ability and other factors, such as determination or self-regulation (Malanchini et al., 2019), create complex systems that are challenging to model, especially under traditional longitudinal frameworks (Watts, 2017)

This inherent complexity suggests great potential for future work, away from effect-centered research and toward the development of theoretical frameworks of cognitive malleability (Katz et al., 2018). Formalizing hypotheses computationally might prove to be a necessary step to propose refined models that go beyond broad, uninformative claims of improvement, and enable individual-level predictions (Farrell & Lewandowsky, 2010; Moreau, 2021; Moreau & Wiebels, 2021). Similarly, refined measurements and explicit estimation of process overlap across the content of interventions and outcome measures will facilitate precise and robust inferences (Moreau & Wiebels, 2021). These are timely issues for the field to consider—efforts toward building computational models of cognitive improvements are in line with recent calls to recognize the importance of theoretical work (Fiedler, 2018; Gray, 2017; Greenwald et al., 1986; Krakauer et al., 2017; Muthukrishna & Henrich, 2019; Smaldino, 2019; Szollosi et al., 2019) and the far-reaching ramifications of measurement issues (Eisenberg et al., 2019; Flake & Fried, 2019; Poldrack & Yarkoni, 2016) in psychology and neuroscience. In the meantime, current gaps in our mechanistic understanding call for caution and should encourage constructive skepticism about cognitive-intervention research (see Table 2).

Table 2. Outstanding Questions.

Focus	Question
Explanatory	Are there moderating variables that can account for the mixed evidence surrounding the effectiveness of cognitive interventions?
Correlational	What are the behavioral and neural dynamics associated with cognitive improvements?
Comparative	How do brief cognitive interventions compare with longer forms of interventions (e.g., education) or with regimens which mechanisms of improvement are hypothesized to be different (e.g., physical exercise, mindfulness meditation)?

Philosophical	Should generalized improvements be the goal?
Societal	What are the implications for society, in terms of policies and decisions? Are current models based on meritocracy outdated given current scientific knowledge?

Consequences of Exaggerated Claims

Acknowledging limitations in our understanding of cognitive malleability is of epistemological concern—an important endeavor to further define underlying processes and mechanisms. Yet given the non-invasiveness and inexpensiveness of cognitive interventions, many researchers and practitioners have argued that there is little cost in large-scale implementations (Rattan et al., 2015), irrespective of our mechanistic understanding; the worst possible outcome of such interventions is a lack of improvement. This view is questionable, however—exaggerated emphasis on cognitive malleability, to the detriment of other, less malleable attributes, brings about a number of serious problems (Moreau et al., 2019).

First, any type of intervention is associated with **opportunity costs** (Moreau, 2021; Moreau et al., 2019; Russell et al., 1996; Simons et al., 2016). Given time constraints, the number of activities, programs or interventions in which one can take part is inherently limited. In school curricula, these opportunity costs are especially salient, as they often involve taking time away from core academic subjects (E. M. Foster et al., 2007). In cases where alternatives are known to benefit individuals and have direct practical implications (e.g., physical exercise, teaching aides, development of specialized educational resources), opportunity costs can also lead to failures to provide adequate assistance to individuals, which themselves can engender more negative outcomes (i.e., **Matthew effect**; (Merton, 1968). Importantly, opportunity costs can differ across interventions—those associated with inexpensive, short-term interventions may be easier to justify than the costs that come with longer, less scalable programs. These differences should be factored in when considering involvement, especially at the institutional level (Kraft, 2020; Lortie-Forgues & Inglis, 2019).

Beyond direct trade-offs stemming from the choice of an intervention over another, a number of other negative effects are more pernicious. Constant focus on effort or change has the potential to stigmatize individuals in a profoundly debilitating way (Moreau et al., 2019;

Nathan, 2017), perhaps best illustrated in the context of learning disorders. When surrounded by claims that remediation is a matter of effort and perseverance, parents and educators are led to believe that "children with learning disabilities can change their lives by improving cognitive functioning" (Eaton, 2010). This rhetoric is dangerous, because it does not acknowledge how profound some of these learning disorders are, and how limited change may be (Chacko et al., 2014; Goswami, 2015; Shaywitz & Shaywitz, 2005; van der Donk et al., 2015). If a child does not improve over time when exposed to seemingly evidence-based remediation programs, the conclusion is often that she must not be doing enough. Examples abound in the mindset literature; for example, Rattan and colleagues (2015) state: "students with fixed mindsets avoid challenges [...] dislike effort [...], and give up more easily when facing setbacks" (p. 722). Similarly, Dweck (2009) mentions that "people with a fixed mindset believe that if you have natural talent, you shouldn't need much effort" (p. 5).[3] The implicit assumption is that effort, much more than cognitive ability, is self-regulated—one can simply decide to work more or to give up. Yet this is an assertion that requires substantiation; as with cognitive abilities, effort and perseverance appear to be relatively stable traits across the lifespan (Digman, 1989), with strong genetic correlates (Lo et al., 2017; Rimfeld et al., 2016). Although they do not imply that these traits cannot be changed, as claimed by extreme **genetic essentialism**, these findings do suggest that we, as a society, need to be careful about what implicit premises are shaping our expectations, for ourselves and for others.

From Scientific Evidence to Policy

The notion that cognitive abilities are largely malleable is especially appealing to progressive, liberal, democratic societies, following on from a number of policies that were implemented with the general goal—either direct or indirect—to reduce individual differences. In the past century, nutrition programs and dietary guidelines have helped millions of children develop normally (Jahns et al., 2018), universal healthcare has allowed dramatic improvements in population health (Navarro et al., 2006), and compulsory

[3] Dweck has revisited this assumption in an opinion piece for *Education Week* in 2015, claiming: "effort is key for students' achievement, but it's not the only thing. Students need to try new strategies and seek input from others when they're stuck. They need this repertoire of approaches—not just sheer effort—to learn and improve" (https://www.edweek.org/leadership/opinion-carol-dweck-revisits-the-growth-mindset/2015/09). However, the stronger claims equating mindset with effort have found widespread support among peers and practitioners, with far-reaching implications across fields and professions (see Burgoyne et al., 2020, for a direct test of this particular premise of mindset theory).

education for all children has facilitated social integration and economic prosperity (Gathmann et al., 2015). On the surface, recent movements acclaiming cognitive malleability are not unlike large-scale policies successfully implemented in the past—they stem from recognizing the presence of barriers in the way of individual achievement, and constitute an effort to remedy salient societal problems.

Although these efforts are laudable, it is also important that society and popular opinion do not get ahead of current scientific knowledge. When science and society are misaligned, distorted expectations and unachievable goals can arise, in an unhealthy climate that fosters frustration (Wrosch et al., 2003, 2007). Arguably, the scientific pursuit is about what is true, rather than what is convenient, or in line with our core values, even if that means pointing out differences between individuals. This does not imply that researchers bear no responsibility with respect to how their findings are being used, and possibly distorted, but the question of truth remains different from that of implications. As a case in point, research in genetics has uncovered myriad differences between individuals, yet how these have been mischaracterized by deviant groups to justify atrocities and discrimination can hardly be taken as a criticism of the empirical evidence itself. Identifying individual differences and limits to cognitive malleability is a step toward implementing collective actions that can benefit everyone.

Beyond ethical considerations at the individual level, one could argue that deliberately emphasizing the malleability of our cognitive abilities may in some instances be beneficial. For example, economies might thrive in contexts where individuals believe they can change beyond what science suggests, in a dynamic that encourages them to surpass themselves. Yet this view ignores the psychological cost of failure (Nathan, 2017)—individuals who constantly fall short of expectations, both theirs and those set by society, are on average less happy (Bühler et al., 2019), more depressed (Gamble et al., 2019), and less likely to hold a job (Lallukka et al., 2019); all aspects which themselves hinder success (Shamir, 1986) and prosperity (Radcliff, 2001). The cost is not just individual; distorted expectations also generate an unnecessary burden for society.

The issue runs deeper than its manifestation in psychology or neuroscience. Underlying many of these extreme ideas is the notion that underachievement is not primarily driven by genetic attributes or structural scarcity, but by failures to view oneself as malleable or to exercise self-discipline. Not only is this idea false, it is dangerous—if chance or society are not the major determinants of individual successes and failures, it is tempting to explain away societal injustice (Nathan, 2017), in line with the **just-world fallacy** (Lerner & Miller, 1978; Lerner & Simmons, 1966). When unchallenged, this view can become a barrier to appropriate interventions, decisions and policies (Furnham, 2003). Although I do not claim that the proponents of cognitive-intervention research whose work I discuss in this paper support this view, nor that they in any way embrace it, the unintended consequences of overstating the role of environmental factors in success are pernicious and not confined to academic research, and as such need to be closely considered (Moreau et al., 2019). The meaningful development of individual aptitudes and abilities is a process that likely takes time, consistent with research in education (Ritchie & Tucker-Drob, 2018; Stine-Morrow & Payne, 2015): early learning and interactive reading have well-documented effects on long-term abilities, yet they require sustained effort (Protzko et al., 2013).

Concluding Remarks

Given the promise of significant change with little investment or resources, cognitive interventions are appealing to a wide range of individuals and institutions. In many respects, however, robust scientific evidence to confirm these benefits is still lacking, and the underlying mechanisms of improvement remain poorly understood (see Table 2). For now, caution is thus required, especially when these findings are used to support large-scale policies. Individual differences in human ability are profoundly complex—a view that recognizes these differences, rather than stigmatize them or further a rhetoric of extreme cognitive malleability, is one that is not only more accurate, but also provides the foundations for a fair and just society.

Boxes

Box 1. The Generalizability Paradox

One of the most debated questions in the pursuit of generalized cognitive improvement via behavioral interventions is that of **transfer**—the capacity for a given training regimen to generalize outside of the training context. Training is said to transfer if it elicits improvements that can be measured on tasks different from those that were part of the training regimen. Phrasing this distinction as a dichotomy is an oversimplification, however; some assessment tasks depart from those of training regimens but remain relatively similar, others are completely different. Acknowledging this granularity has led to the distinction between *near* transfer, when tasks are thought to measure the same underlying construct or ability, and *far* transfer, when tasks tap into different constructs. Although this distinction is helpful, in that it illustrates the notion that the question of transfer is not a dichotomous one, it is unlikely to go far enough, with transfer perhaps being best modeled as a continuum (Baltes et al., 1989; Baltes & Willis, 1982); Fig. 1).

Over a century of research in psychology has shown that our aptitudes can be developed via learning, but that the best way to improve is to practice on the task of interest (Noack et al., 2009; Stine-Morrow & Basak, 2011). Only on rare occasions (e.g., ceiling effect, clinical conditions) does practice not result in improvements. In contrast, cognitive interventions often target core abilities that are thought to influence many others in order to elicit generalized improvements, including gains on different abilities. This is the case for popular paradigms such as working memory (Harrison et al., 2013; Jaeggi et al., 2008; Redick et al., 2013) or attention (Tang & Posner, 2009) training, perhaps akin to preseason conditioning for athletes in many sports. However, because transfer from one ability to another remains limited at best (Gobet & Sala, 2020; Sala & Gobet, 2019), some training regimens are designed to target a range of cognitive abilities, so as to maximize the likelihood of ecological benefits (Buitenweg et al., 2017). Research using multi-ability paradigms is more encouraging than for single-task or single-ability regimens (Cheng et al., 2012), yet the overall view remains that robust evidence for generalized improvements is lacking (Simons et al., 2016).

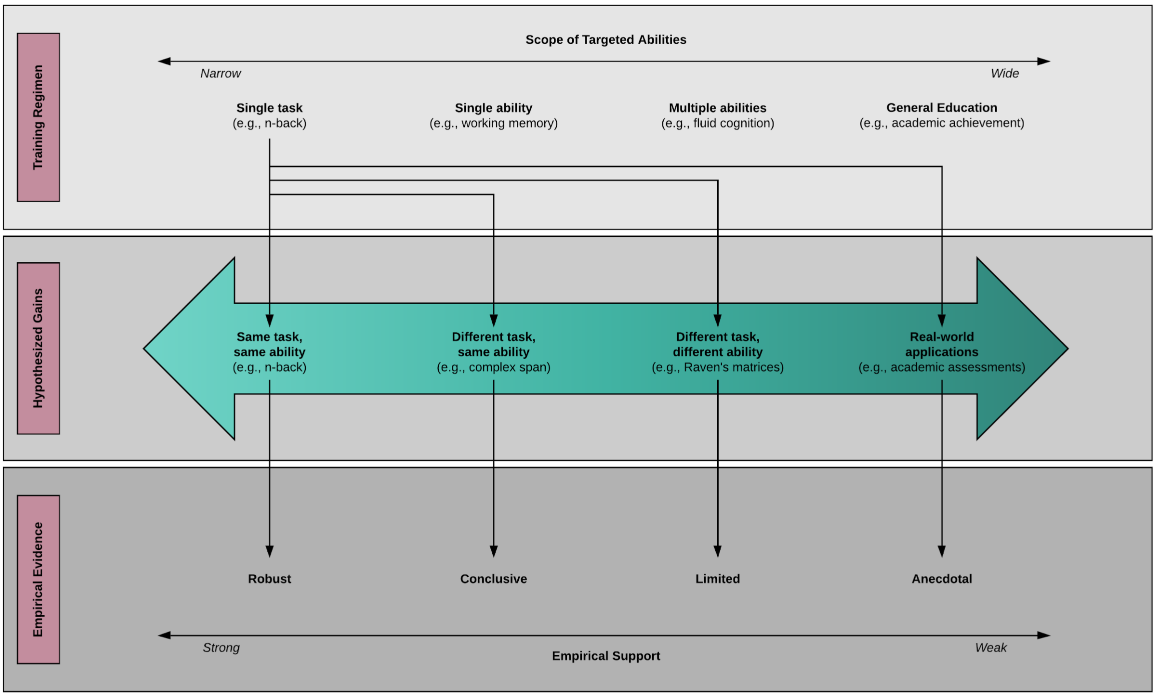

Figure 1. Brain training and cognitive improvements. *Top:* Scope of abilities targeted by cognitive training, from single tasks to general education. *Middle:* Continuum of hypothesized gains, ranging from no transfer (left) to near, far and real-world transfer (right). *Bottom:* Empirical support for the claims of transfer. The descending arrows show the relationship between single-task training regimens (the most common type of regimen in the literature), hypothesized gains, and corresponding empirical evidence.

Box 2. The Mindset Circularity Problem

In a typical mindset intervention (Dweck, 2008), a group of children is told that "the brain is like a muscle" (growth mindset group), whereas others are given scientific facts about the brain without any reference to its plasticity (control group). After the intervention, researchers typically measure outcomes such as how much effort students showed on a set of problems or how well they performed on a test. There are a number of issues with this type of intervention, mainly stemming from the lack of adequate control and blinding to conditions.

First, the similarity between the intervention and outcome measures means that the research hypothesis cannot be plausibly concealed from participants. It is thus likely that participants will behave in accordance with researchers' expectations—i.e., **Hawthorne effect** (French, 1953); see also Boot et al. (2013)—a risk potentially exacerbated given the ubiquity of mindset posters in classrooms around the globe (Denworth, 2019). As a result, mindset interventions may work within research settings, but not generalize to contexts where expectancy effects are more nuanced (Brougham & Kashubeck-West, 2017; Foliano et al., 2019)—an assumption consistent with the absence of clear association between growth mindset and either academic persistence (Macnamara & Rupani, 2017) or academic achievement (Aronson et al., 2002; Furnham et al., 2003; Sisk et al., 2018).

Second, there is no indication that the growth message component really is what elicits benefits, an idea supported by findings showing that interventions that promote reflecting on the relation between schoolwork and life goals ("sense-of-purpose" interventions) show the same benefits as growth-mindset interventions (Paunesku et al., 2015). In other words, we cannot infer whether effects truly are influenced by valuable information about abilities, or perhaps simply by being told a positive, empowering story. Mindset proponents sometimes argue that the malleability of cognitive abilities is demonstrated by mindset interventions (Dweck, 2008), but this line of reasoning is circular—even if believing that cognitive abilities are malleable does benefit individuals in some ways, this has no implications for the empirical question of whether abilities really are malleable.

Box 3. The Subgroup Specificity Fallacy

A number of cognitive interventions follow up on null effects with subgroup analyses. These analyses often yield significant effects for specific subgroups—for example, low performing students (Paunesku et al., 2015), individuals with lower cognitive abilities (Jaeggi et al., 2008), or participants whose training performance showed particular characteristics (Jaeggi et al., 2011)—and typically interpret these findings as evidence for the intervention being effective (or more effective) for specific populations. Unless these analyses are preregistered and interpreted with caution (e.g., Yeager et al., 2019), however, they present a number of issues (Cui et al., 2002; Oxman & Guyatt, 1992; Pocock et al., 2002; Tidwell et al., 2014).

Randomized controlled interventions are designed to compare groups; for example, an experimental group vs. a control group. Randomization provides safeguards against a number of confounds when comparing these *specific* groups, but not when these are broken down into subgroups. A classic example is with low-performing individuals on a baseline measure—if their difference scores are considered in isolation, these individuals will tend to show improvements on subsequent measurements because of regression-to-the-mean effects

(Moreau et al., 2016; Nesselroade et al., 1980; Smoleń et al., 2018), irrespective of treatment effects (see Fig. 2). Although this particular fallacy has become rare in major publications, it remains surprisingly common in the broader field of cognitive interventions.

Other problems with subgroup analyses are more subtle. For example, brain training interventions often include analyses contrasting responders on the training regimen (i.e., individuals who show the greatest gains on the training task) with non-responders, in order to compare these subgroups on the outcome variable of interest (Tidwell et al., 2014). This type of analysis is problematic, as it is possible that individuals who show greater response to the training regimen also possess other characteristics making them more likely to show post-intervention improvements (e.g., motivation, awareness of experimenter's expectations, floor effect, etc.).

Finally, a major issue with subgroup analyses comes with the associated flexibility in data analysis; subgroups can be created in many different ways within a variable, and for many potential variables. In all cases, the solutions are straightforward—subgroup analyses should be predefined, ideally in the form of a preregistration; exploratory subgroup analyses should be clearly labeled as such, and confirmed in subsequent studies (Mellor & Nosek, 2018; Moreau & Wiebels, 2021; Nosek et al., 2018). When many subgroup analyses are performed, they should preferably be combined in multilevel analyses, rather than assessed independently.

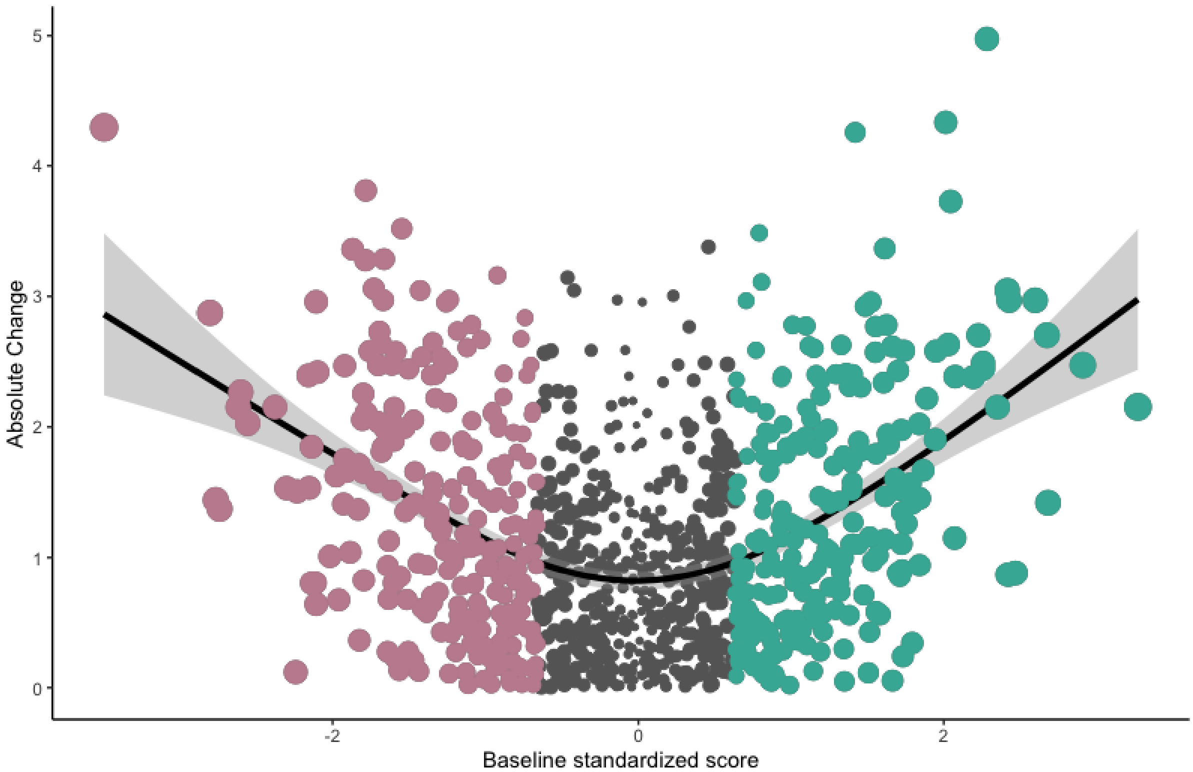

Figure 2. Regression to the mean in subgroup analyses. The graph shows the relationship between baseline scores on an outcome variable and the change from baseline to post-intervention, for a simulated intervention with no effect (N = 1,000, M = 0, SD = 1, for both baseline and post-intervention scores, assuming Gaussian distributions and no test-retest effects). The size of the dots represents the observed regression-to-the-mean effect. Regression to the mean is a direct consequence of baseline scores; extreme scores will tend to regress toward the mean, creating the illusion of a treatment effect. If one isolates a group based on baseline score (e.g., low performers, pink dots), it will seem to improve greatly over the course of the intervention compared to average performers (gray dots). However, the same would happen if one were to isolate high performers instead (green dots)—this phenomenon is a statistical artifact.

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