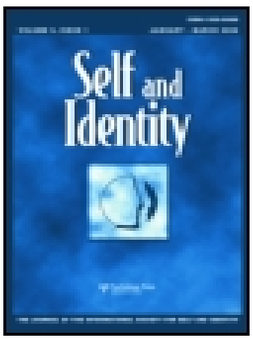

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ARTICLE

Directed abstraction during initial skill learning promotes performance and lasting self-concept change

Peter V. Zunick[a] and Russell H. Fazio[b]

[a]Department of Psychology, Centenary College of Louisiana, Shreveport, USA; [b]Department of Psychology, The Ohio State University, Columbus, USA

ABSTRACT

Learning a new skill is often characterized by discouraging setbacks. We administered a directed abstraction writing exercise to encourage participants struggling to learn a programming language (over three weekly sessions) to generalize broadly from their successes. This intervention produced benefits for certain subsets of participants, including those who initially struggled to learn, believed their abilities were changeable, and had negative initial self-concepts regarding computers and programming. The benefits of directed abstraction included more positive self-concepts, motivation, and even performance one month following the final learning session. These results expand on past findings, showing benefits of directed abstraction over time and in a realistic learning setting, while further exploring for whom directed abstraction has the greatest benefits.

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Self-concept; motivation; learning; performance

Learning a new skill is challenging. Imagine trying to learn to play the piano with no prior musical training. One would invariably encounter setbacks and failures, beginning almost immediately and continuing throughout the learning process. However, besides this steady stream of failures, new learners typically experience success as well, and how struggling learners deal with their failures may be partly determined by how much they capitalize on these successes. Learners who generalize broadly from their successes (e.g., drawing positive conclusions about their musical abilities) may be better able to stay motivated and engaged despite their failures, resulting in persistence and a greater likelihood of eventual proficiency. Conversely, learners who do not generalize from their successes may instead conclude from their failures that they lack some ability or talent necessary for piano playing, which may decrease motivation, engagement, persistence, and eventually performance. Thus, helping learners maintain at least somewhat positive self-beliefs early in the learning process may provide numerous benefits, both immediate and downstream.

The current research tests whether a brief writing intervention called directed abstraction helps learners capitalize on early successes, leading to positive self-concept change and increased performance over time. Previous research (Zunick, Fazio, & Vasey, 2015) developed the directed abstraction technique and demonstrated that when administered following a success, the technique improves participants' self-concepts (e.g., their beliefs about

CONTACT Peter V. Zunick pzunick@centenary.edu Centenary College of Louisiana, Shreveport, USA
Supplemental data for this article can be accessed here.

their abilities; Studies 1–3) and, in one instance, performance (specifically, persistence following failure; Study 4). This past work involved short-term laboratory experiments that assessed only immediate outcomes and not the development of self-concept change over time. The current research examines the effects of directed abstraction on both self-concept and performance outcomes as participants learn a new skill (HTML coding) over the course of three weekly sessions, with the primary outcome measures assessed one month later. Besides the longitudinal timeframe that better matches how most skill development naturalistically occurs, we also used ecologically valid learning materials from the popular website Codecademy.com. In addition, whereas past work suggested directed abstraction benefits participants with negative self-concepts, we explored other moderators as well, including how much participants initially struggled during the learning process and their implicit theories of intelligence (Dweck & Leggett, 1988).

Reactions to success and directed abstraction

Negative self-views can prevent learners from fully benefiting from a success. For instance, a beginning piano student may arrive at her first lesson already believing she is a slow learner, lacks musical talent, or is undisciplined, and these beliefs may interfere with her ability to generalize from her successes. More broadly, there is abundant evidence that general self-esteem biases reactions to success. Compared to their low self-esteem counterparts, people with high self-esteem easily generalize from successes, developing more positive beliefs about their abilities, past performances, and future performances, along with increased motivation (e.g., Critcher & Dunning, 2009; Jussim, Yen, & Aiello, 1995; Kernis, Brockner, & Frankel, 1989; Shrauger & Rosenberg, 1970; Wood, Heimpel, Newby-Clark, & Ross, 2005). Self-verification theory (Swann, 1983, 2011), which suggests people prefer verifying existing self-views to changing them, provides a theoretical framework for understanding these findings. If the goal is to confirm one's current self-beliefs, then people with low self-esteem should prefer negative feedback, act in ways to elicit it, and discount their successes.

Directed abstraction promotes positive self-concept change following a success, especially among those with negative self-views who are thus prone to negative self-verification (Zunick et al., 2015). The technique consists of a writing prompt guiding participants to think of the success in abstract, personal terms, considering its broad implications regarding their abilities. The prompt begins, "Explain WHY you were able to achieve this success." Both the "explain why" question (Freitas, Gollwitzer, & Trope, 2004) and "were able to achieve" verb phrase (DePoot & Semin, 1995; Semin & Fiedler, 1988, 1991) encourage abstract generalizations that transcend the particulars of the event (Trope & Liberman, 2010).

However, abstract generalization in and of itself may not be helpful, because such abstraction may lead individuals with negative self-views to dismiss the positive implications of their success. Hence, the abstraction must be directed toward a positive inference. It is for this reason that the directed abstraction prompt directs participants to abstract in a positive manner. Specifically, in addition to being abstract, the verb phrase "were able to achieve," presupposes that the individual was responsible for the success, a tactic drawn from research on how question wording can shape one's views of an event (e.g., Loftus & Palmer, 1974). Previous research (Marigold, Holmes, & Ross, 2007, 2010) combined these two elements, the "explain why" question and an abstract, directed verb phrase, to help participants low in self-esteem benefit from compliments from their romantic partners

("Explain why your partner admired you. Describe what it meant to you and its significance for your relationship."). Our directed abstraction technique is, in essence, a more generalized version of that earlier intervention designed for use in any success context. It also adds one additional linguistic framing device to direct how participants generalize, asking them to begin their response by completing a sentence stem ending with, "because I am … ", a technique drawn from past research on how sentence stem completions affect what information is most salient to a respondent (Salancik, 1974). This sentence stem is most naturally completed with self-descriptive adjectives or nouns, which are abstract parts of speech that often imply enduring traits (e.g., "talented," "a hard worker;" Bryan, Master, & Walton, 2014; Semin & Fiedler, 1991).

Directed abstraction guides participants to draw their own conclusions rather than providing those conclusions for them, which is important for several reasons. First, self-generated responses are privileged in attention and memory (Slamecka & Graf, 1978). In addition, telling a struggling, self-doubting piano student that she is musically talented may fail or even backfire due to self-verification motives (Swann, 2011), attribution principles (Brummelman et al., 2014), or psychological reactance (Brehm, 1966). Directed abstraction circumvents these barriers by allowing participants to generate an abstract, personal explanation for their success that they find credible. For example, one struggling piano student might concede she has a good sense of rhythm, while another might admit he is disciplined and hard-working.

Current goals

Past research showed that, when administered following a success, directed abstraction led to increases in ability beliefs, performance expectations, self-related affect (e.g., pride), and, in one study, persistence in the face of failure (Zunick et al., 2015). We consider the first three outcomes to concern changes in the self-concept, while the fourth is a measure of actual performance. These effects appeared across four laboratory studies and three skill domains (estimation ability, public speaking, and verbal aptitude). However, this research left several important questions unanswered.

First, would the same results occur if directed abstraction were used in a realistic, ecologically valid setting in which participants learn a tough new skill over the course of several weeks? In the current study, participants learned HTML, a programming language used to build webpages, via a self-paced online course offered by the popular website Codecademy.com. Thus, despite the learning sessions taking place in a controlled lab setting, participants learned from the same materials as 45 million other aspiring programmers (Codecademy, n.d.). In addition, by using three weekly learning sessions, the current research mimicked how people often learn actual skills, over time. By using a real skill, real learning materials, and multiple sessions, this research better approximated a real-life learning context than a typical single-session lab-based psychology study.

Second, what are directed abstraction's long-term benefits? Practically speaking, a useful intervention should have effects that persist beyond the brief time-frame of a single-session study. In addition, one of the more interesting theoretical aspects of directed abstraction is its potential to trigger cascading psychological benefits. One can imagine a beginning piano student whose belief that she is musically talented leads to pride and excitement, which leads to increased motivation and engagement, which leads

to more regular practice and improved playing, which may even lead back to increased ability beliefs, starting the cycle anew. To begin exploring such questions, we assessed the primary dependent variables in the current study one month after the third and final experimental session.

Third, whereas previous work demonstrated benefits of directed abstraction for people with negative self-concepts (generally low self-competence or, in one experiment, concerns about public speaking ability; Zunick et al., 2015), would directed abstraction also benefit people struggling with self-doubt that emanates from other sources? Just as someone who believes she is uncoordinated and has no sense of rhythm may view her successes learning piano as isolated incidents bearing no implications for her overall piano-playing abilities, so too might the learner who believes she is well-coordinated and rhythmically gifted but unexpectedly struggles during her first several piano lessons. Both learners may experience self-doubt that prevents them from generalizing from their successes, and as such, both may benefit from directed abstraction. In the current research, we examine both self-concept and performance-related moderators of directed abstraction effects.

Fourth, might participants' views of their abilities as malleable vs. fixed moderate the benefits of directed abstraction? Incremental theorists (i.e., those who believe their abilities are changeable and improvable) enjoy a host of benefits compared to entity theorists (i.e., those who believe their abilities are stable and fixed; Dweck, 2006; Dweck & Leggett, 1988). For instance, whereas incremental theorists strive to learn and grow, entity theorists prefer to demonstrate their existing abilities; the former goals are, unsurprisingly, more conducive to positive outcomes than the latter (Dweck & Leggett, 1988; Grant & Dweck, 2003). In addition, incremental theorists attribute their failures to lack of effort, which facilitates improvement, whereas entity theorists do not (Hong, Chiu, Dweck, Lin, & Wan, 1999). We wondered whether directed abstraction might be most effective for incremental theorists, perhaps because believing they can change their abilities makes these individuals more open to the related idea of changing their ability beliefs, at least when given the right nudge. Conversely, perhaps directed abstraction would be most effective for entity theorists, whose maladaptive beliefs position them as the individuals with the most room to benefit from an intervention like directed abstraction. Either finding would contribute to the burgeoning literature on the effects of implicit theories. We had no reason to prefer one prediction over the other (or over the null hypothesis) and thus viewed this particular question as purely exploratory.

In the current experiment, participants completed exercises from a self-paced HTML course during three weekly lab sessions, each including a directed abstraction manipulation. We tested whether directed abstraction produced benefits to self-concept, motivation, and performance outcomes at a one-month follow-up session, either as main effects or, more likely, moderated by one of several theoretically relevant variables. We predicted that directed abstraction would lead to increased self-concept and motivation outcomes at the one-month follow-up, especially for participants who initially had negative self-concepts about computers in general (hypothesis 1) or who initially struggled to learn (hypothesis 2). Regarding performance, we predicted directed abstraction would lead to increased performance on an HTML knowledge quiz at the one-month follow-up, especially for participants who initially had negative self-concepts (hypothesis 3). We also explored whether the effects of directed abstraction on both self-concept and performance outcomes might differ based

on participants' implicit theories, though we had no a priori predictions regarding specific patterns of moderation.[1]

Method

We report all exclusions, manipulations, and measures (although some measures not central to our hypotheses appear only in the online supplement). We performed several exploratory analyses between the third and fourth sessions but did not base sample size decisions on those analyses; rather, our stop rule was to run as many participants as possible in one semester. Regarding statistical power, because the current study's method was so dissimilar to past research using the directed abstraction technique, we had little basis for estimating effect sizes for a priori power analyses. Instead, we collected as many participants as time and resources allowed while striving to maximize effect sizes by making the study as immersive, realistic, and impactful as possible. Given the study's sample size, sensitivity analyses indicated 80% power to detect an effect size of $f^2 = .12$ for the two 3-way interactions predicting the primary dependent variables at the one-month follow-up (i.e., those shown in Figures 1 and 4).

Participants

We recruited undergraduate introductory psychology students who reported during a pre-screening session having little or no programming experience but being willing to learn. Participants received partial course credit and an entry in a $25 Amazon gift card drawing for each session. Of 84 initial participants (48 women, 34 men, 2 unspecified), 9 did not complete all four sessions (4 directed abstraction, 5 control), 1 later reported prior programming experience, and 2 did not consistently provide success experiences during the manipulation (see below). Excluding these 12 yielded a sample of 72 (44 women, 26 men, 2 unspecified).

Procedure

The first three sessions lasted one hour each and occurred roughly one week apart. In these sessions, participants completed HTML learning exercises, a directed abstraction manipulation, and questionnaires. At the start of session 1 we randomly assigned participants to the directed abstraction or control group; participants remained in the same group for all sessions. The fourth session was a 20-minute online survey sent to participants one month after the third session that included questionnaires and an HTML knowledge quiz.

In the first session, participants gave informed consent and received a broad overview of the study, including instructions for how to log into Codecademy.com, complete the learning exercises, and record their progress. They then provided demographic information, completed pretest questionnaires, spent roughly 30 minutes on HTML learning exercises via Codecademy.com, and completed the directed abstraction manipulation. The second and third sessions began with brief instructions. Participants then reviewed material from the prior session (5m) before completing additional learning exercises (15m), the manipulation (5m), questionnaires (5m), and more learning exercises until the session ended (15m). Roughly one month later, participants received a link to the fourth session, an online survey

that included posttest versions of the self-concept questionnaires from session 1, a 20-item HTML knowledge quiz, and a debriefing.

Materials

Codecademy learning exercises

The experimenter logged participants in to Codecademy.com accounts at the start of each session. Participants completed exercises (roughly 1–5m each) from the "HTML/CSS Part 1" learning unit at their own pace. Each exercise included instructions, a workspace to type code, and a preview of the resulting webpage. Codecademy.com automatically checked participants' code when they attempted to submit each exercise, and if it detected errors, prevented them from proceeding. Participants could access an optional hint on some exercises or, if they were truly stuck or experiencing an issue or bug in the Codecademy website, ask for help from the experimenter, who had completed the relevant Codecademy lessons and, hence, was aware of potential issues with the site. At certain points during their progression, participants took five-item multiple-choice quizzes provided by Codecademy covering material from recent exercises. If their first answer on a quiz item was incorrect, participants were required to try again until they chose the correct answer.

Participants recorded the date they completed each exercise on a worksheet, which permitted us to calculate the number of exercises completed in each session. We reasoned that participants who completed relatively few exercises during a session were likely experiencing difficulties and struggling to learn. This interpretation seems especially plausible given that Codecademy did not allow participants to proceed to the next exercise if their code for the current exercise was incorrect; in other words, participants were required to demonstrate some mastery of the material before proceeding. The number of exercises completed in session 1 was best suited for use as a covariate or moderator because those exercises occurred before the first administration of the manipulation.[2]

Directed abstraction manipulation

For each administration of the manipulation, participants identified their biggest success in the current session (onscreen instructions provided examples, such as "Got 4/5 correct on a quiz," and "Got the hang of how links work."). To assess whether participants were able to comply, we next asked them to report how successful the experience was and how difficult it was to recall. Based on their responses, we excluded from further analysis two participants who could not consistently identify successes (i.e., who rated their recalled successes, on average across all three sessions, below the midpoint, labeled *Somewhat successful*).

Participants then responded to one of two writing prompts. The directed abstraction prompt read, "Explain WHY you were able to achieve this success," and requested participants begin with the sentence stem, "I was able to achieve this success because I am . . . " As in past research (Zunick et al., 2015), the control prompt read, "Describe HOW you performed as you did in this situation. What did you do?" with no sentence stem completion. Participants were asked to spend at least 3 minutes responding, after which they could continue to the next part of the experiment.

Session 1 questionnaires

These pretest measures were collected in session 1 prior to the learning exercises and manipulation. See the online supplement for further information.

Achievement goals. We administered a short version of the 9-item Achievement Goal Inventory (Grant & Dweck, 2003). Most relevant to the current analyses was the 3-item learning goals subscale (e.g., "In school I am always seeking opportunities to develop new skills and acquire new knowledge," α = .65). Participants responded from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*).

Implicit theories of intelligence. Three items assessed whether participants viewed their overall intelligence as fixed entities or as incrementally improvable (e.g., "You can learn new things, but you cannot really change your basic intelligence," α = .92; Hong et al., 1999). Participants responded from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). Higher numbers indicate entity theories and lower numbers incremental theories.

Experience with computers. Past research on directed abstraction in the public speaking domain used the extent of participants' past experience with public speaking as an important covariate (Zunick et al., 2015). Similarly, in the current research participants likely had varying amounts of past experience working with computers. We therefore adapted the three public speaking experience items to instead measure experience with computers (e.g., "I have had a lot of experience over the years working with computers," α = .64). Participants responded from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*).

Computer ability beliefs. We based this scale on an outcome measure from past research (Zunick et al., 2015). Seven items assessed participants' beliefs about their computer-related abilities (e.g., "Overall, I am good at dealing with computers," α = .92). Participants responded from 1 (*Strongly Disagree*) to 7 (*Strongly Agree*).

HTML performance expectations. We also based this scale on an outcome measure used in past research (Zunick et al., 2015). Seven items assessed participants' performance expectations in hypothetical scenarios involving HTML (e.g., "You want to build yourself a personal website from scratch using HTML," α = .89). Participants responded from 1 (*I would do VERY POORLY*) to 9 (*I would do VERY WELL*).

Programming motivation. These four items assessed motivation to learn programming, both HTML and other languages (e.g., "I wouldn't mind working in a job that required advanced, high-level programming," α = .82). Participants responded from 1 (*Strongly Disagree*) to 7 (*Strongly Agree*).

Prospective HTML-related affect. We based this scale on an outcome measure used in past research (Zunick et al., 2015). It assessed the extent to which thinking about learning HTML made participants feel each of eight emotions, four positive and four negative (e.g., Proud, Ashamed; α = .70 after reverse-scoring negative emotions), from 1 (*Not at all*) to 4 (*Very much*).

Sessions 2 and 3 questionnaires

In sessions 2 and 3, after the manipulation, participants completed posttest versions of four measures from session 1 (HTML ability beliefs, HTML performance expectations, HTML motivation, and retrospective HTML-related affect). These measures were identical to their session 4 counterparts, described below.

Session 4 questionnaires

Four of the five measures described below were similar to pretest measures from session 1. A pure pretest-posttest design with identical measures at each time point was impossible because some scale items only made sense once participants had experience with HTML. These items were either omitted or modified for the pretest. We describe below the five posttest measures that we deemed on an a priori basis to be most relevant to the hypotheses; five less relevant, more exploratory, measures appear in the online supplement.

HTML ability beliefs. This measure was similar to the computer ability beliefs scale from session 1, but referenced HTML rather than general computer skills (e.g., "Overall, I am good at HTML") and had eight items ($\alpha = .92$) rather than seven.

HTML performance expectations. This measure was similar to its session 1 pretest counterpart, but had eight items ($\alpha = .95$) rather than seven.

HTML motivation. This scale was similar to the programming motivation scale from session 1, but had seven items ($\alpha = .94$) rather than four and assessed participants' motivation for both programming in general and HTML specifically (e.g., "I want to continue building my HTML skills once this study is over").

Retrospective html-related affect. This measure was similar to the session 1 prospective HTML-related affect scale, with the same eight items, but asked participants how thinking back on their experiences learning HTML made them feel ($\alpha = .80$).

Programming interest. This measure, which had no direct pretest counterpart, assessed participants' interest in learning five non-HTML programming languages (e.g., "Java – a common programming language used for things like smartphone apps, advanced website functions, and business applications," $\alpha = .93$). Participants responded from 1 (*Not at all interested*) to 7 (*Very interested*).

Session 4 HTML knowledge quiz

This quiz included 20 multiple-choice questions (e.g., "Which tag has the highest default font-size? <p>, , <a>, or <h1>"). It covered novice material from early exercises all participants completed, intermediate material from later exercises not all participants reached, and advanced material participants never saw and could only infer based on a deep understanding of what they did cover. Critically, participants who completed more exercises had the chance to learn more of the quiz material, so how many total exercises participants completed was an important determinant of quiz scores.

Results

We first computed scale means and, using the progress tracking worksheets, coded participants' progress (i.e., exercises completed) for session 1 (representing initial struggles, pre-manipulation) and sessions 1–3 (representing total material covered). We then checked for failures of random assignment on pre-manipulation session 1 variables and detected one: higher scores on the Achievement Goal Inventory's learning goals subscale for the control group (M = 4.29, SD = .42) than for the directed abstraction group (M = 4.01, SD = .51), $t(70) = 2.53$, $p = .01$. We controlled for learning goals by including this variable as a covariate in all subsequent analyses.

Self-concept and motivation outcomes

We hypothesized that directed abstraction would produce positive self-concept and motivation change in session 4 especially for participants with initially negative self-concepts regarding computers and HTML (hypothesis 1) or who initially struggled to learn (hypothesis 2), and we speculated that implicit theories might also play an important moderating role. To simplify these analyses, we condensed the five key session 4 outcomes (HTML ability beliefs, HTML performance expectations, HTML motivation, retrospective HTML-related affect, and programming interest) into a single self-concept/motivation composite variable. These five variables represent either core aspects of one's HTML-related self-concept (e.g., HTML ability beliefs) and motivation (e.g., programming interest) or closely-linked constructs that may be direct consequences of these variables (e.g., HTML-related affect). These five variables also represent ways of generalizing from an HTML success to something broader (e.g., self-beliefs, affective responses, other programming languages). Methodologically, these variables all required participants to make self-inferences, in contrast to our behavioral measure, quiz performance. Empirically, the five variables correlated positively ($.41 < r < .84$, mean $r = .63$), loaded on a single factor explaining 62.4% of the variance, and showed similar patterns of results. Because these variables were related to each other both empirically and conceptually, as well as for ease of presentation and increased statistical power, we analyzed a composite of the five variables as our dependent variable. Interested readers are referred to the online supplement for summaries of analyses of each individual variable.

To create the self-concept/motivation composite, we standardized and then averaged the five variables (M = 0, SD = .84). In subsequent analyses, we removed one extreme outlier on the composite variable (3.09 SDs from the sample mean) and included as covariates three session 1 variables that correlated positively with the session 4 composite: learning goals (r = .23, p = .056; also included due to the failure of random assignment), experience with computers (r = .38, p = .001), and an initial, pre-manipulation session 1 self-concept/motivation composite (r = .72, $p < .001$) created by standardizing and averaging computer ability beliefs, HTML performance expectations, programming motivation, and prospective HTML-related affect.

Regression analyses provided no evidence for a main effect of condition on session 4 self-concept/motivation, nor for an interaction between condition and initial self-concept/motivation. However, analyses revealed significant interactions between condition and the other two hypothesized moderators, session 1 progress and implicit theories.[3] In the first model, session 4 self-concept/motivation was predicted from condition, session 1 progress, their interaction,

and three covariates (learning goals, experience with computers, and initial self-concept/motivation), each of which had been assessed prior to the experimental manipulation. We standardized the outcome variable, as well as all predictor variables but condition (control = 0, directed abstraction = 1) prior to computing the interaction term. The interaction between condition and session 1 progress was significant, $b = -.39$ [95% CI: −.74, −.05], $t(63) = -2.30$, $p = .03$, R^2 change = .04, $f^2 = .08$, and simple effects analyses revealed a significant effect of directed abstraction for participants with relatively low session 1 progress scores (1 *SD* below the mean), $b = .57$ [.06, 1.07], $t(63) = 2.24$, $p = .03$, but not for participants with relatively high session 1 progress scores (1 *SD* above the mean), $b = -.22$ [−.69, .25], $t(63) = -.95$, $p = .35$. The second model, which was identical but replaced session 1 progress with standardized implicit theories, also produced a significant interaction, $b = -.51$ [−.86, −.16], $t(64) = -2.92$, $p = .005$, R^2 change = .06, $f^2 = .13$, with simple effects analyses showing a significant effect of condition for participants with relatively incremental theories (1 *SD* below the mean), $b = .59$ [.11, 1.07], $t(64) = 2.44$, $p = .02$, but not for participants with relatively stronger entity theories (1 *SD* above the mean), $b = -.44$ [−.93, .06], $t(64) = -1.77$, $p = .08$.

Moreover, when all three variables (condition, session 1 progress, and implicit theories) were allowed to interact, a significant 3-way interaction emerged (Figure 1). This model predicted session 4 self-concept/motivation from condition, session 1 progress, implicit theories, all three 2-way interactions, the 3-way interaction, and the same three covariates (learning goals, experience with computers, and initial self-concept/motivation), with all variables standardized prior to computing interaction terms but condition (control = 0, directed abstraction = 1). The 3-way interaction was significant, $b = .42$, 95% CI [.05, .80], $t(59) = 2.24$, $p = .03$, R^2 change = .03, $f^2 = .09$. Simple effects analyses revealed a significant 2-way interaction between condition and session 1 progress for participants with relatively incremental theories (1 *SD* below the mean), $b = -.71$ [−1.24, −.18], $t(59) = -2.69$, $p = .009$ (Figure 1, left), but not for participants with relatively entity theories (1 *SD* above the mean), $b = .14$ [−.37, .64], $t(59) = .54$, $p = .59$ (Figure 1, right). Given relatively incremental theories (Figure 1, left), directed abstraction boosted session 4 self-concept/motivation scores for participants with lower session 1 progress scores (1 *SD* below the mean), $b = 1.16$ [.54, 1.77], $t(59) = 3.78$, $p = .0004$, but not for those with higher session 1 progress scores (1 *SD* above the mean), $b = -.27$ [−1.09, .55], $t(59) = -.66$, $p = .51$. For these incremental theorists, session 1 progress significantly predicted session 4 self-concept/motivation scores for the control

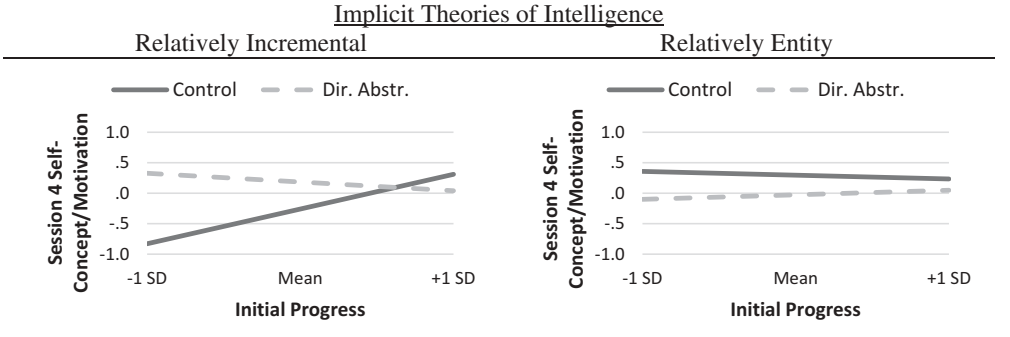

Figure 1. Session 4 self-concept/motivation composite predicted by condition, session 1 progress, implicit theories of intelligence, and their interaction.

group, $b = .57$ [.20, .94], $t(59) = 3.12$, $p = .003$, but not the directed abstraction group, $b = -.14$ [−.51, .22], $t(59) = -.79$, $p = .43$.[4]

These results revealed that directed abstraction had positive effects for a specific subset of participants: those who made relatively little initial progress on the HTML learning modules in the first session, prior to the manipulation, and who also had relatively incremental implicit theories of intelligence. Moreover, the benefits produced by directed abstraction were evident on self-concept/motivation variables at session 4, which occurred one month after the final experimental session.

Although the above analysis controlled for several important pre-manipulation session 1 variables, it did not track how the effects seen at session 4 emerged over time. Our next step was thus to conduct a growth curve analysis examining the trajectory of the four self-concept/motivation variables measured in some form in each of the four sessions, and whether those trajectories differed based on condition, session 1 progress, implicit theories, and their interaction. This analysis was conceptually similar to the 3-way interaction just reported, but with the additional moderator of time. To reduce the number of analyses and simplify interpretation, we followed the same strategy as before of creating a composite self-concept/motivation variable, only this time we created a separate composite for each session after standardizing each of the four variables across all four sessions (HTML/computer ability beliefs, HTML performance expectations, HTML-related affect, and HTML motivation; we did not include programming interest, which was only measured in session 4).[5]

We ran a mixed-effects growth curve analysis with session nested within participants (Singer & Willett, 2003) predicting the self-concept/motivation composite from condition (control = 0, directed abstraction = 1), session 1 progress, implicit theories, session (coded 1 through 4), and all interactions up to and including the 4-way, along with session 1 learning goals and experience with computers as covariates. In growth curve analyses, the effect of time may be linear or non-linear (Singer & Willett, 2003), and adding a quadratic term for session in this model revealed a significant quadratic effect, $b = -.19$ [−.23, −.15], $t(69) = -9.23$, $p < .001$. The model included a randomly varying intercept, randomly varying slopes for both the linear and quadratic session parameters, and an unstructured covariance matrix. Including the quadratic session term and allowing both session slopes to vary randomly each significantly improved model fit (ps < .001).

This analysis revealed a significant 4-way interaction between condition, session 1 progress, implicit theories, and time (i.e., session 1–4), $b = .06$ [.01, .11], $t(62) = 2.48$, $p = .02$. The pattern of results for participants with relatively entity implicit theories (1 *SD* above the mean) remained mostly unchanged across the four sessions (Figure 2, right); that is, the simple 3-way interaction for more entity theorists was not significant, $b = .02$ [−.04, .08], $t(62) = .73$, $p = .47$. Thus, entity theorists did not appear to benefit from directed abstraction in terms of self-concept/motivation outcomes relative to their initial, pre-manipulation session 1 levels on these variables. However, the pattern of results for participants with relatively incremental theories (1 *SD* below the mean) did change over time (Figure 2, left); this simple 3-way interaction for more incremental theorists was significant, $b = -.09$ [−.15, −.03], $t(62) = -2.89$, $p = .005$. Specifically, the condition by session 1 progress interaction for relatively incremental theorists was absent at session 1, pre-manipulation, $b = -.06$ [−.25, .13], $t(60.54) = -.57$, $p = .57$, beginning to emerge at session 2, $b = -.14$ [−.33, .04], $t(60.27) = -1.46$, $p = .15$, statistically

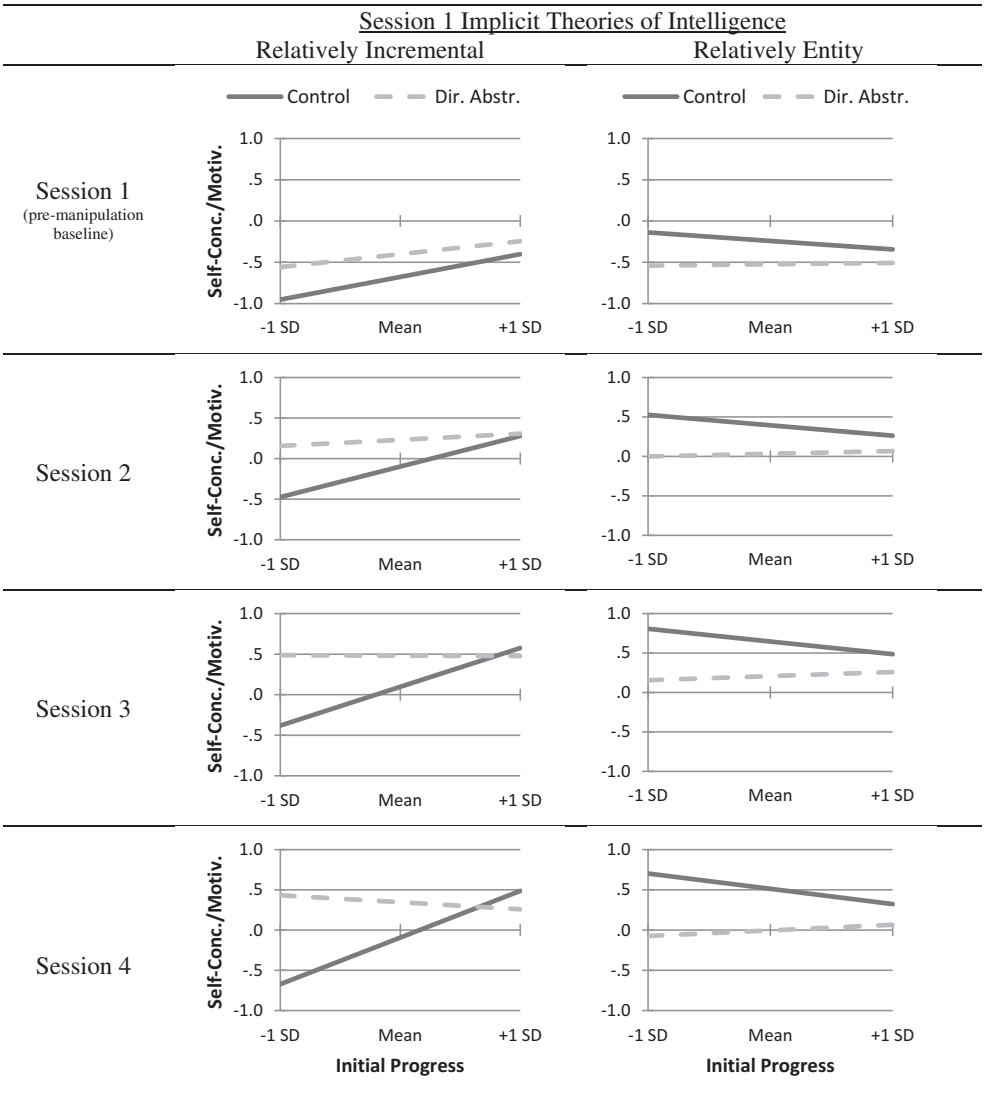

Figure 2. Self-concept/motivation composite predicted by the interaction of session, condition, initial progress, and session 1 implicit theories of intelligence, in a growth curve model with a random intercept and random slopes for the linear and quadratic session effects.

significant at session 3, $b = -.23$ [−.43, −.03], $t(62.45) = -2.16$, $p = .03$, and strongest at session 4, $b = -.32$ [−.55, −.09], $t(64.51) = -2.61$, $p = .01$.[6]

This model demonstrates that the pattern of results that emerged when focusing only on session 4 outcomes (Figure 1) was absent in session 1, prior to the manipulation, and only emerged over time, as can be seen on the left side of Figure 2. Further simple effects analyses revealed that for participants with relatively incremental implicit theories (1 *SD* below the mean) and relatively low session 1 progress (1 *SD* below the mean), the effect of condition was absent at session 1, prior to the manipulation, $b = .39$ [−.05, .84], $t(60.34) = 1.65$, $p = .10$, but as the experiment progressed the condition effect emerged and grew: at session 2, $b = .63$ [.19,

1.07], $t(60.17) = 2.67$, $p = .01$; at session 3, $b = .87$ [.39, 1.34], $t(61.55) = 3.38$, $p = .001$; and at session 4, $b = 1.11$ [.55, 1.65], $t(62.81) = 3.75$, $p < .001$. Figure 3 shows the simple 2-way interaction of condition and session for participants with relatively incremental theories and low session 1 progress, $b = .24$ [.10, .38], $t(62) = 3.18$, $p = .002$, illustrating the emergence of the condition effect across time for this subset of participants.

Quiz performance

We scored the session 4 HTML knowledge quiz as the proportion of correct answers out of 20 ($M = .66$, $SD = .15$). As expected, these quiz scores correlated positively with session 4 self-concept/motivation composite scores, $r = .41$, $p < .001$. Those participants with more positive self-concepts and motivation concerning HTML coding performed better on the quiz.

We also computed the total number of exercises completed across all three learning sessions, reasoning that any analysis of knowledge acquisition should account for how much information participants were exposed to initially.[7] This exposure variable was indeed related to quiz scores ($r = .42$, $p < .001$), as were the three previous covariates: learning goals ($r = .30$, $p = .01$) experience with computers ($r = .21$, $p = .09$), and initial self-concept/motivation ($r = .40$, $p < .001$). Because there is no plausible mechanism by which directed abstraction could help participants recall information they were never exposed to in the first place, we included the exposure variable in the following analysis, as well as interactions of this variable with condition and initial self-concept/motivation (including the 3-way interaction). We expected participants exposed to relatively little material during the three learning sessions to perform poorly on the HTML knowledge quiz regardless of condition, whereas participants exposed to relatively more material would benefit more from directed abstraction.

Initial regression analyses showed neither a main effect of condition nor an interaction of condition and either exposure or initial self-concept/motivation alone. However, there was a marginally significant 3-way interaction (Figure 4) involving all three predictors: condition, exposure, and initial self-concept/motivation, $b = -.48$ [−.97, .02], $t(57) = -1.91$,

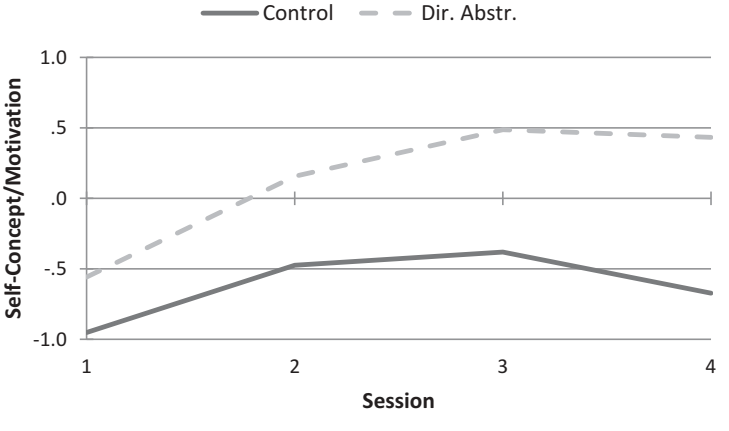

Figure 3. Simple 2-way interaction of condition and session at 1 *SD* below the mean of both implicit theories and session 1 progress.

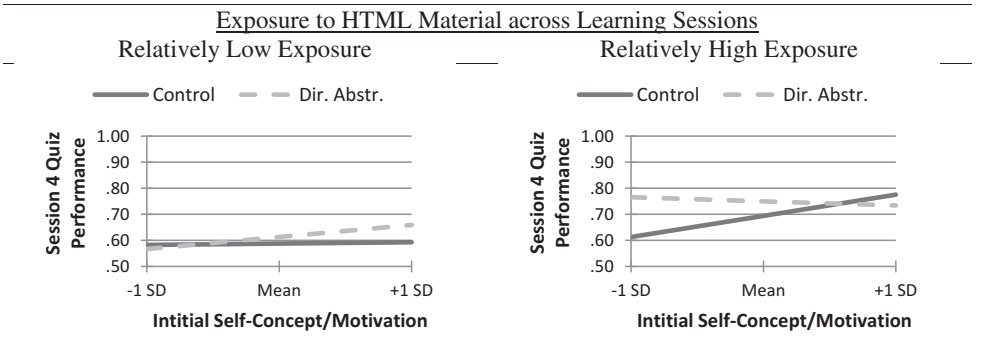

Figure 4. Session 4 quiz score (proportion correct) predicted by the interaction of condition, exposure, and participants' initial pre-manipulation session 1 self-concept/motivation composite.

p = .06, R^2 change = .04, f^2 = .06, in a model controlling for learning goals and experience with computers and with the outcome variable standardized, as well as all predictor variables but condition (0 = control, 1 = directed abstraction), prior to computing interaction terms. Simple effects analyses revealed a significant 2-way interaction between condition and initial self-concept/motivation for participants exposed to relatively more material (1 *SD* above the mean), b = −.67 [−1.32, −.02], $t(57)$ = −2.07, p = .04 (Figure 4, right), but not for those exposed to relatively less material (1 *SD* below the mean), b = .28 [−.42, .99], $t(57)$ = .80, p = .43 (Figure 4, left). Given greater exposure (1 *SD* above the mean), condition significantly predicted higher quiz scores for participants with lower initial self-concept/motivation (1 *SD* below the mean), b = 1.05 [.08, 2.03], $t(57)$ = 2.17, p = .03, and the effect of initial self-concept/motivation was only significant for participants in the control group, b = .56 [.08, 1.04], $t(57)$ = 2.35, p = .02.[8]

Discussion

Hypotheses 1 and 2 concerned the effect of directed abstraction on self-concept and motivation outcomes. In support of hypothesis 2, directed abstraction provided self-concept and motivational benefits for participants who initially struggled to learn HTML. Presumably, early difficulties led these participants to doubt their abilities, but directed abstraction helped them overcome these doubts and capitalize on their successes. This finding both confirms past research on the benefits of directed abstraction (Zunick et al., 2015) and extends that work to a new skill domain, a new set of outcomes, and most importantly, a longitudinal timeframe for learning a new skill. However, these beneficial effects only occurred for struggling learners who viewed their overall abilities as changeable, rather than fixed. Thus, incremental theories may be a necessary precondition to fully benefit from directed abstraction, at least on self-concept and motivational outcomes. This finding fits with past research showing that fostering more incremental mind-sets helps struggling, at-risk students perform better academically, presumably by helping them persist when encountering difficulty (Paunesku et al., 2015). Entity theorists may interpret struggles during learning as signs they lack a fundamental skill or ability necessary for success, rendering directed abstraction useless, whereas incremental

theorists may be more open to the idea that they have some ability despite their struggles, leaving the door open for directed abstraction to facilitate these ability beliefs. Future research should explore the exact mechanisms by which implicit theories interact with the generalization processes sparked by directed abstraction, but in the meantime, our results suggest that facilitating the effects of directed abstraction should be added to the already-long list of the benefits of incremental theories (Dweck, 2006).

One unexpected finding was that entity theorists who initially struggled with HTML ended the study with relatively positive self-views regardless of condition. That is, their self-concepts were not damaged by their initial struggles (Figure 1, right side). Perhaps entity theorists ignore initial failures in order to rigidly maintain their existing self-views during the early stages of learning. It is possible this rigidity is initially adaptive and leads to persistence in learning, which would be a novel benefit of entity theories, otherwise generally considered maladaptive. This possibility is speculative and was not the main focus of our research, but future research should explore how entity theorists respond to difficulties early in the learning process. Whereas past research has generally found that entity theorists respond poorly to failure (e.g., Dweck & Leggett, 1988; Hong et al., 1999), there may be specific instances in which entity theorists respond more adaptively to difficulties learning a new skill than incremental theorists. Any such possibility would represent a significant contribution to the field's understanding of how implicit theories operate in different learning situations. Nonetheless, the overall pattern of results in the current study, in which incremental theories facilitate the benefits of directed abstraction for learners who initially struggle, fits well with past research and theory.

We did not find support for the prediction that directed abstraction would provide the greatest boost to the self-concepts and motivation of participants entering the study with negative self-concepts regarding their computer abilities (hypothesis 1). Past research did find that directed abstraction's effects on self-concept variables were moderated by participants' initial self-concepts (Zunick et al., 2015). This past research used single-session designs. Over the extended time frame of the current study, participants' accumulating experiences with HTML may have overshadowed whatever relevant beliefs they began with concerning their more general computer abilities. The prior studies also used ability domains that were somewhat familiar to participants (e.g., public speaking, ability to solve anagrams), so their initial self-beliefs may have been especially relevant. In the current study, the novelty of HTML coding may have rendered participants' initial self-beliefs regarding their computer skills less relevant than their more salient, ongoing experiences with the HTML learning modules, at least in terms of influencing participants' affective, motivational, and self-concept-related inferences.

On the other hand, participants' initial self-views did influence whether directed abstraction improved the objective measure of learning, their quiz performance. Initial self-views, as indicators of relatively low computer abilities, may have affected how participants approached the learning exercises and the resulting skill development they experienced. More negative self-views appear to have prompted less beneficial interactions with the learning exercises, as is apparent from the relation observed between participants' initial self-views and their quiz scores in the control condition, given sufficient exposure to the relevant material during learning (Figure 4, right side). Directed abstraction attenuated this relationship, presumably by helping those with initially

negative self-views interact with the learning exercises in a more beneficial way. Future research should replicate these differing patterns and explore what factors determine whether or not directed abstraction effects are moderated by one's initial self-views.

Some readers may wonder whether boosting people's self-concepts and motivation early in the learning process is even adaptive. That is, does directed abstraction lead people to unrealistically positive and potentially maladaptive illusions about their abilities? There are four reasons to doubt this is the case. First, positive illusions may be adaptive (e.g., Taylor & Brown, 1988), especially early in the learning process. If beginning piano students truly understood the trials and tribulations necessary to achieve proficiency, would anyone choose to learn to play piano, or other difficult skills like computer programming? Second, learning a brand new skill may involve more failures than successes, whereas the learning process may become more balanced once one has achieved basic proficiency. Similarly, when first learning a new skill, failures may seem especially insurmountable, whereas successes seem trivial and ungeneralizable. If so, directed abstraction could help beginners overcome this bias in the early learning process and reach the more sustainable and balanced intermediate level. Third, our composite dependent variable included not only direct self-concept measures (i.e., ability beliefs), but also related constructs involving emotional experiences and motivation. One can argue it is maladaptive for learners who lack competence at coding to believe they are talented; it is harder to argue that learners can be too excited about, or interested in, HTML, or that they should not take pride in their successes. Fourth, inspecting the means (available for all variables in the online supplement) reveals that participants were not, on average, claiming outrageously high levels of ability (e.g., the mean on the session 4 ability beliefs scale was 5.08 out of 7). For these reasons, we believe the self-concept and motivational benefits of directed abstraction are adaptive when people are learning a new skill.

One advantage of our roughly six-week longitudinal design is that we could examine how participants' self-concepts and motivation changed over time. As can be seen in Figures 2 and 3, participants' experienced the greatest gains early in the learning process, from sessions 1 to 2. Subsequent gains leveled off as participants reached more difficult content in sessions 2 and 3, and during the month between sessions 3 and 4, some of those gains seem to have disappeared, at least for participants in the control condition. In this context, the benefits of directed abstraction for incremental theorists who initially struggle appear not only as gains accrued over the course of the learning sessions, but also as a tendency for those gains to persist over time. This finding is consistent with previous research and theory characterizing time as an important dimension along which abstraction occurs (Trope & Liberman, 2010). Participants in the control condition may have viewed their successes as isolated incidents with little meaning outside the bounds of the specific three-week learning period, whereas directed abstraction may have helped participants abstract beyond the three learning sessions and consider the implications of their successes for their current and future selves during the one-month follow-up.

Our methodology allowed us to assess not only self-report outcomes, but also objective performance. In support of hypothesis 3, directed abstraction boosted performance on the HTML knowledge quiz for participants with initially negative self-concepts. It is likely that by insulating these participants from self-doubts stemming from their negative self-views, directed abstraction facilitated a deeper engagement with the learning process. Self-doubts may simply distract learners, or they may lead learners to defend their self-esteem against the threat of failure by disengaging from the task. Both would result in

rote completion of learning exercises without deep processing, nuanced encoding, or extensive elaboration of the material, which past work suggests is important for learning and recall (e.g., Craik & Lockhart, 1972). In support of this idea, directed abstraction only boosted the performance of learners who completed many exercises and thus had a chance to engage with and learn most of the quiz material. This result is compatible with the idea that directed abstraction made participants interact with the exercises in a way that improved their later recall and performance. If there had been a direct, unmediated route by which directed abstraction boosted quiz performance irrespective of the learning exercises, then the performance boost would not have been contingent on how much information participants were exposed to during the learning exercises. Future work should explore exactly how directed abstraction facilitates performance, but our results suggest these effects occur at the learning and encoding stage.

Interestingly, in contrast to the self-concept and motivational outcomes, the effects of directed abstraction on quiz performance were not moderated by implicit theories. This result raises the intriguing possibility that implicit theories play a different role in shaping one's self-concept and motivation than in shaping one's actual performance. However, given the exploratory nature of our analyses involving implicit theories, future research is needed to address this question more fully.

The current study's methodology allowed for relatively high psychological realism. Computer programming is an important skill many people seek to learn. Our participants learned via Codecademy.com, a self-paced, adaptive, online learning setting that not only claims to have helped 45 million users learn to code, but that is broadly representative of how many people learn new skills in the modern era. Such research is important because learners taking online college courses face difficulties that those in hybrid or fully face-to-face courses do not (Escueta, Quan, Nickow, & Oreopoulous, 2017). In particular, massive open online courses, which are generally available to anyone with internet access, suffer from high dropout rates (Perna et al., 2014). Initial research suggests learners' motivation and interest (Kizilcec & Schneider, 2015), and especially their self-efficacy (Barak, Watted, & Haick, 2016; Cho & Heron, 2015), are important predictors of their engagement in these online learning environments. Directed abstraction could be useful both as a research tool in this burgeoning field of inquiry and as a practical intervention to maintain students' motivation to continue such online learning programs.

Another aspect of this study's psychological realism is the extended timeframe. Past work showed immediate benefits of a single administration of directed abstraction, but in real life people do not have one encounter with a difficult task and stop. Rather, they have repeated encounters and learn over time. In terms of outcomes, the most important benefit of a success experience may not be how one feels about oneself immediately, but how one feels weeks, months, or even years later. By including three learning sessions and following up one month later, the current study demonstrates the benefits of directed abstraction over a more ecologically valid timeframe than most psychology studies provide.

Finally, our research findings add to the literature on using principles of linguistic abstraction (e.g., Freitas et al., 2004; Salancik, 1974; Semin & Fiedler, 1991) to influence how people subjectively construe some stimulus or event (e.g., Bryan et al., 2014; DePoot & Semin, 1995; Kross & Ayduk, 2011; Watkins, Moberly, & Moulds, 2008). Inspired by a similar intervention encouraging people with low self-esteem to generalize from compliments from their romantic partners (Marigold et al., 2007, 2010), our directed abstraction exercise was designed as

a general-purpose antidote to the tendency exhibited by some people to resist generalizing from success (Zunick et al., 2015). That initial research on directed abstraction focused on instances in which peoples' negative self-views might prevent them from generalizing from success due to self-verification motives (Swann, 2011). The current results broaden the scope of directed abstraction, suggesting new situations in which directed abstraction is useful (initial skill learning, and especially online learning), new classes of individuals who can benefit from this technique (i.e., those struggling with self-doubt due to initial learning difficulties rather than initially negative self-views), new ways these benefits might manifest (i.e., increased motivation and changes in how one interacts with and thus learns computer-administered material), and important ways these effects interact with participants' implicit theories of how changeable their abilities are (Dweck, 2006).

Follow-up research should assess the extent to which this study's specific pattern of results is generalizable to different samples, learning methods, time spans, and ability domains. For instance, would different patterns emerge for people taking a year of one-on-one piano lessons, or foreign language learners enrolled in a one-month immersion program, or someone trying to build a patio in a weekend by watching carpentry videos online? These are open questions that are of both practical and theoretical interest. However, generally speaking, the current research and past work (Zunick et al., 2015) consistently show that directed abstraction provides benefits for people who encounter reasons to doubt their abilities. We expect future research will continue to add nuances and details to this picture while confirming its general outlines.

Notes

1. Regarding both self-report and performance outcomes, because we had no basis for predicting whether each moderator would operate independently of the others (separate two-way interactions) or in combination (a three-way interaction), we remained open to either possibility. Also, note that we predicted moderation by initial struggles for the self-concept and motivation outcomes but not performance. This was not based on conceptual reasoning, but simply necessitated by our operationalizations. As we discuss later, it is unreasonable to expect directed abstraction to improve quiz performance for material participants never reached in the self-paced, programmatic learning exercises. Therefore, our analyses of quiz performance were necessarily moderated by participants' total progress over all three sessions, i.e., the amount of material to which they were exposed. This exposure variable was naturally confounded with our operationalization of initial struggles, which was how many exercises participants completed in the first session. We were therefore unable to assess whether effects of directed abstraction on performance were moderated by initial struggles independent of overall progress.
2. Of course, completing few exercises could plausibly reflect a lack of interest instead of, or in addition to, learning struggles. However, participants' reports of their initial motivation to learn programming were unrelated to the number of exercises they completed in session 1, $r = .05$, $p = .66$.
3. One participant had missing data for session 1 progress and was excluded from subsequent analyses involving this variable.
4. Omitting the covariates slightly decreased the 3-way interaction's p-value (.004) and did not noticeably change the overall pattern of results. Including the outlier did not change either the p-value (.03) or the overall pattern.
5. We standardized these variables across all sessions, not within sessions (similar to grand-mean centering rather than group-mean centering). Standardizing the variables within-session instead would have artificially removed all between-session mean differences.

6. Omitting the covariates did not affect the significance of the 4-way interaction (p = .02). Including the outlier identified in the previous analyses slightly decreased the interaction p-value (p = .009).
7. Four participants had missing data for at least one of the three sessions and were excluded from the subsequent analyses.
8. Omitting the covariates made the 3-way interaction significant (p = .04) but changed the pattern of results such that the simple 2-way interaction at relatively high total progress was not significant (p = .09). Including the outlier slightly reduced the 3-way interaction's p-value (p = .05) and left the simple 2-way interaction unchanged (p = .04).

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Disclosure statement

No potential conflict of interest was reported by the authors.

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