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Scientific identity and STEMM-relevant outcomes: Elaboration moderates use of identity-certainty☆

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ABSTRACT

This research investigates the link between scientific identity and STEMM (Science, Technology, Engineering, Mathematics, and Medicine)-related outcomes as a function of identity certainty. Across a pilot study and three additional studies, participants' scientific identity was first measured using different procedures. Then, the certainty with which that identity was held was either measured (pilot study and Studies 1 & 2) or manipulated (Study 3). Both subjective outcomes (e.g., interest and career decisions in the pilot study and Study 2) and objective consequences (e.g., performance in Studies 1 and 3) served as dependent variables. As expected, results showed that participants' scientific identity was more strongly associated with STEMM-relevant outcomes as certainty in that identity increased. Beyond predicting when and for whom scientific identity is more likely to guide career decisions and performance, this research showed that reliance on identity certainty (a metacognitive assessment) is more likely to occur as the extent of thinking is increased. By inducing elaboration after certainty was already manipulated (Study 3), this research distinguishes between forming a metacognitive judgment of certainty and subsequently using that already existing certainty.

There is a growing interest in understanding how people come to decide to engage in careers in science, technology, engineering, mathematics, and medicine (STEMM) fields. Previous research has shown that recruitment and retention of students into STEMM majors is more likely for individuals who hold a scientific identity, and therefore see themselves as possible scientists (Chemers et al., 2011; Dou et al., 2019; Jones et al., 2020; Seyranian et al., 2018). For example, Vincent-Ruz and Schunn (2018) found that scientific identity was related to the number of STEMM-relevant activities that students chose to engage in during high school. Beyond high school, scientific identity has proven fruitful in predicting choices, behavior, and persistence in careers related to STEMM fields (Ahlqvist et al., 2013; Carlone & Johnson, 2007; Gainor & Lent, 1998; Hazari et al., 2013; Perez et al., 2014; Zirkel, 2002).

Scientific identity also has been associated with better performance in STEMM-related tasks. In fact, several studies have found that students who identify as scientists are more likely to perform well in science careers (e.g., Carlone & Johnson, 2007; Eccles & Barber, 1999; Ong, 2005; Osborne & Walker, 2006). For example, Chen et al. (2021) found that identifying as a "science person" was associated with higher grades and higher performance in STEMM-related tasks (e.g., answering correctly questions about biology, chemistry, mathematics, etc.).

Although prior evidence generally has supported the positive relationship between scientific identity and STEMM-relevant decisions and actions, some exceptions to this association have been shown (e.g., Cameron et al., 2020). Therefore, it is important to specify when and for whom scientific identity is more likely to guide decisions and behaviors relevant to STEMM. The first goal of the current research is to examine whether certainty in one's identity could moderate the relationship between scientific identity and STEMM-relevant outcomes. As will be described, this prediction is based on Self-Validation Theory (SVT, Petty et al., 2002; Briñol & Petty, 2022) that postulates that any mental construct that is held with higher levels of certainty is more impactful on subsequent evaluations and behaviors. A second important goal of the present work is to specify for the first-time a moderating condition for the use of identity certainty in impacting relevant outcomes.

Self-Validation Theory.

As noted, the idea that identities held with certainty would be more impactful in guiding judgments and behaviors is consistent with SVT. This approach provides an integrative framework for understanding why, when, and for whom initial cognitions (e.g., thoughts, identity,

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personality, etc.) are more predictive of judgment and behavior. The core notion of SVT is that any mental content, including scientific identity, becomes more consequential for judgment and action as the certainty in that mental content increases. Perceptions of validity (or certainty) are a form of metacognition since they involve thinking about one's initial cognitions (Briñol & DeMarree, 2012; Petty et al., 2007). SVT is particularly useful because it has proven applicable to many dimensions along which people vary including traits, dispositions, chronic thinking styles, personality, and many other mental contents (see Briñol & Petty, 2022, for a review).

Initial evidence for the role of certainty moderating the association of identity and identity-related outcomes has been investigated previously in the domain of national identity and sacrifice for one's group. For example, Paredes et al. (2020) asked participants to complete a scale of identity fusion with their country (Gómez et al., 2011; Swann Jr. et al., 2010). Then, participants reported their confidence in their responses to the identity fusion scale. These two variables served as predictors of the willingness to fight and die for their country. Consistent with SVT, results showed that identity fusion was a significant predictor of willingness to fight and die, especially when people reported higher certainty in their identity. This initial work reveals that certainty can play a role in this context relevant to identity and extremism.

The current research focuses on the effects of identity certainty in guiding identity-behavior correspondence, particularly for the first time in the domain of scientific identity predicting STEMM relevant outcomes such as interest in STEMM fields, career choices and performance. In addition, the current research introduces several conceptual and methodological novelties beyond the contribution of Paredes' et al. (2020). Specifically, the prior work by Paredes and colleagues exclusively used correlational designs to investigate the relationship between identity fusion with one's country and reported intentions to self-sacrifice for one's country. Thus, the present research has the potential to advance that initial work by generalizing to a different domain (from one's county to science) to a different identity measure (from identity fusion with one's country to traditional forms of scientific identity), and most uniquely by manipulating rather than just measuring certainty. The current work also examines a measure of actual behavior rather than just behavioral intentions. Therefore, the present research applies SVT to a totally different (but still important) domain of identity (scientific identity) with some methodological refinements (greater causal inferences with respect to certainty and examining the effects on actual behavioral outcomes).

Importantly, beyond replicating and expanding on this initial evidence, the present research also has the potential to conceptually advance SVT by examining the role of elaboration not only in the experience or formation of identity-certainty but also in the use of this already formed certainty. That is, this research was designed to examine the SVT prediction according to which the utility of identity-certainty is especially high under conditions in which thinking is relatively high.[1] As described next, we based our prediction about moderation of the use of identity-certainty on SVT.

[1] Elaboration is a mental process that comes from people's motivation and ability to engage in extensive thinking before making a judgment. Beyond processing information deeply, elaboration involves attempting to access relevant associations, images, and experiences from memory, scrutinizing these associations, and drawing inferences from them (Petty & Cacioppo, 1986). Factors examined in the present studies, such as reports of subjective elaboration (Barden & Petty, 2008), and individual differences in need for cognition (Cacioppo & Petty, 1982) are both well-established assessments of elaboration. Furthermore, manipulations of personal relevance and mental load inductions (Study 3) are the dominant approaches to manipulating elaboration and they have been shown to systematically influence the motivation and capacity to think, respectively (Kredentser et al., 2012; Tormala et al., 2002). In the present research, elaboration and thinking will be treated interchangeably.

1. Experiencing vs. using certainty

Metacognitive processes include two stages: metacognitive experiences and metacognitive use of those experiences. For example, a person can first have a metacognitive experience associated with their identity (e.g., feeling that one's identity as a scientist comes to mind easily) which can affect their certainty in that identity (cf., Tormala, Petty, & Briñol, 2002; 2007). Second, the individual can use that metacognitive assessment (e.g., certainty from ease) to determine the influence of that identity on relevant decisions and actions. Although having metacognitive experiences and using those experiences are often correlated, research has shown that they are conceptually and empirically distinct (Briñol et al., 2004; Briñol, Petty, et al., 2007; Clark & Thiem, 2015; Clark et al., 2011; Clarkson et al., 2011; Noah et al., 2018; Norman et al., 2019; Petty et al., 2002; Yahalom & Schul, 2013). For example, individuals can experience low certainty in a scientific identity but fail to consider this metacognition before making a decision, thus still relying on identity to guide behavior. People can also experience high certainty in a scientific identity but still act as if they were not identified with that field if they do not take that certainty into consideration when making decisions. In other words, having a metacognitive experience does not necessarily guarantee that it will impact subsequent judgment or behavior. Of course, not having the experience precludes its use. In those cases in which metacognitive assessments are generated but not implemented, a person with high certainty would act identically to another person with low certainty, failing to take those differential metacognitive assessments into consideration. This distinction between metacognitive experience and use is similar to other differentiations in the metacognition literature, such as the difference between metacognitive monitoring and control, respectively (Dunlosky & Metcalfe, 2008; Nelson, 1990; Norman et al., 2019). Thus, regardless of whether a person identifies as a scientist or not, the person can have (and experience) different degrees of certainty in that identity. But only when people engage in the second stage, metacognitive usage, will the certainty in scientific identity determine whether the person relies on their identity to guide behavior.[2]

We rely on SVT to guide our predictions about identity certainty and the moderating role of elaboration because SVT is a framework that deals not only with variables that determine whether or not metacognitions are formed, but also with *when* people are more likely to use those metacognitive assessments. Specifically, SVT postulates that metacognitive processes (both experiences and usage) become more likely to occur when thinking is increased: Because considering certainty is a metacognitive process, it takes more thought to generate such metacognition and then use that metacognition than it does to not engage in metacognitive processes.

Prior research beyond SVT has also suggested that the amount of thinking can be relevant to metacognitive processes in general (e.g., Efklides, 2006; Koriat, 2007; Nelson, 1990) and to the first stage of "experience" (e.g., Tugtekin & Odabasi, 2022). However, this prior work has not examined the role of elaboration in distinguishing between different metacognitive stages. Also, previous SVT is ambiguous regarding the role of elaboration because it does not provide distinct evidence about the generation versus use of metacognition. For example, some SVT studies showed that the validating variables impacted certainty more for high thinking individuals or conditions, suggesting that thinking influenced the generation of metacognition (e.g., Briñol, Barden, & Petty, 2007; Briñol, Petty, et al., 2007; Clark &

[2] Forming, having, and experiencing certainty will be treated as interchangeable to refer to the first metacognitive "experience" stage. As noted, that stage of having metacognition can be distinguished from the second stage that refers to the usage or the reliance on that metacognition. Therefore, usage and reliance will also be treated interchangeable to refer to the second metacognitive stage.

Thiem, 2015). However, other studies showed that the validating variables affected certainty for both high and low thinking individuals equally, suggesting that the impact of thinking was on the use of metacognition (e.g., Petty et al., 2002; Tormala et al., 2006).

The novelty of the present research lies in distinguishing between these two metacognitive stages (formation vs. usage) manipulating the extent of thinking after inducing certainty, and therefore controlling (rather than simply measuring) that thinking is not influencing the formation of certainty. Study 3 of the present research is especially relevant to this distinction. In this third study, rather than measuring or manipulating thinking at the beginning of the study as prior research did, thinking was manipulated following the initial certainty induction and therefore once the experience of certainty had already been established. Thus, this work is the first that manipulated thinking once the certainty was already formed thereby ensuring that elaboration is important not only for generating but also for using metacognitive judgments.

The implication for the current work is that, for identity-certainty to be consequential, not only must people consider their identity, but they also need some motivation and ability to engage in additional thought about the validity of that mental content (i.e., making a metacognitive assessment and then also using that assessment). As described next, elaboration will be measured in Studies 1 and 2 and it will be manipulated after the formation or experience of certainty in Study 3.

2. Overview

The current research examined the role of scientific identity on STEMM-related decisions and behaviors. In particular, the extent to which certainty could strengthen this relationship was investigated (pilot study and Studies 1–3). The present work (Studies 1–3) also was designed to examine the role of the extent of thinking in the experience and use of metacognitive processes. In the final study, elaboration was manipulated after certainty had already been induced, thereby clearly isolating the effect of thinking in the use of already existing certainty.

Studies 1 and 2 tested the extent to which higher scientific identity would be more predictive of STEMM-relevant task performance (Study 1) and career choices (Study 2) and especially so as measured certainty in that identity increased. Importantly, these studies were also designed to examine the SVT prediction that the moderation of identity-behavior correspondence by existing certainty is more likely to emerge when participants reported a higher degree of thinking (measured using simple self-reports of thinking or individual differences in need for cognition). The first two studies used a correlational design in which identity, certainty, and elaboration were all measured and served as predictors of outcomes relevant to STEMM fields. Because certainty and elaboration were measured in these studies, it is possible that other, unmeasured factors could have been confounded with certainty and elaboration (e.g., experience, intelligence). Therefore, Study 3 moved to an experimental design by manipulating certainty and elaboration to infer the causal role of these variables when predicting math performance as a function of scientific identity. Furthermore, Study 3 manipulated elaboration just before the behavioral outcome to isolate its causal role in moderating the use of certainty at the time of the measured behavioral outcome.

As noted earlier, across studies, we expected higher scientific identity to be associated with greater STEMM-relevant outcomes. Both subjective outcomes (e.g., behavioral intentions in the pilot study and Study 2) and objective measures (e.g., performance in Studies 1 and 3) were used as dependent variables. Furthermore, certainty, whether measurer or manipulated, was predicted to moderate identity-behavior correspondence (i.e., the greater the certainty, the greater the relationship between scientific identity and STEMM-relevant outcomes). To the best of our knowledge, that interaction effect would be a novel contribution to the domain of scientific identity.

It is important to note that measuring certainty by directly asking participants about how sure they are in their responses to a scientific identity scale and manipulating certainty, for example, by asking them to recall past episodes in which they felt confident, are two very different operationalizations of what it is ultimately a common construct. When certainty is measured, it can come from multiple sources and those diverse origins can vary in their nature. Differences in measured certainty can come from differences in the content of the responses to the scientific identity inventory, from feelings experienced while answering the scale (e.g., the ease with which responses come to mind), from response-consistency, or even from personality variables (e.g., certainty-related traits). Therefore, in the case of self-reports, certainty can come either from content-dependent origins, from content-independent variables (like ease and/or dispositional certainty), or from a combination of both. Importantly, certainty (whatever its origin might be) becomes associated with participants' perceptions of their own scientific identity. Also of relevance is that certainty is a subjective perception of how valid people think their identity is. There is no way of assessing how accurate the certainty really is in the context of judging the self (unlike when judging knowledge about the capital of a country, or when estimating the size of a city).

Importantly, unlike the measurement approach used in Studies 1 and 2, Study 3 manipulated certainty by randomly assigning people to recall past episodes of confidence vs. doubt. In this case, the origin of confidence is completely incidental to scientific identity. Therefore, a unique feature of SVT is that it makes similar predictions for certainty regardless of whether certainty arises from origins related to the initial responses or from origins unrelated to initial responses and thus unrelated toscientific identity. Predicting and demonstrating that operationalizing certainty through these different approaches can produce the same SVT predicted effects is a strength of this research. It provides convergent validity for our different procedures.

Beyond that contribution, the present work was also designed to examine the SVT prediction that the impact of identity certainty on identity-behavior correspondence would be more likely to occur as elaboration increased. There are two reasons why elaboration was expected to moderate the impact of certainty on identity-behavior correspondence. First, it could be that elaboration is more likely to lead to the formation or experience of certainty (i.e., without high elaboration there would be no certainty to use). Second, elaboration could also lead to greater use of certainty once it already has been formed. It is important to clarify that this research is focused on examining the role of elaboration on the second stage (use of certainty). To isolate that second step, the final study manipulated elaboration after (rather than before) identity and certainty were already formed. The predicated three-way interaction between scientific identity, certainty, and elaboration was tested in the following three studies.[3]

3. Pilot study

The primary goal of the pilot study was to obtain evidence for the general relationship between scientific identity and interest in STEMM fields, and to test to what extent certainty would moderate that association. First, students were asked to complete a validated measure of scientific identity. Then, participants were asked to rate how certain they were of their response to the identity measure. Next, they were asked to report their interest in STEMM fields. It was expected that scientific identity would predict interest in STEMM fields. Most relevant, we predicted that certainty would moderate the association of scientific identity and STEMM interest (i.e., the greater the extent of certainty in one's identity, the larger the correspondence between identity and interest in STEMM fields).

[3] The online supplementary file includes the correlations and descriptive statistics for all variables for each of the studies. Furthermore, the supplement also includes information about the Chronbach's alpha of the identity scale as a function of certainty across the three main studies.

4. Method

4.1. Participants and design

Five hundred and two undergraduates at a university in Spain (421 females, 75 males, and 6 unidentified) participated anonymously in this study.[4] The age of the participants ranged from 18 to 50 ($M_{age} = 19.67$, $SD = 1.93$). Measured scientific identity and the certainty associated with that identity were the predictor variables. STEMM interest served as the dependent variable. Our final sample size was determined by the number of participants that we were able to collect during the two weeks in which the study was posted ($N = 502$). This sample size provided 0.80 power to detect an interaction effect size of Cohen's $f^2 = 0.016$ using a two-tailed test and a power of 0.80.

4.2. Procedure

Upon arrival, participants were told that they were taking part in an experiment to test some materials for future research. First, participants were asked to complete a measure of scientific identity. Next, participants reported their certainty in their response to that measure. Then, participants were asked to report their interest in STEMM fields. Finally, participants completed ancillary measures, were thanked, debriefed, and dismissed.

4.3. Predictors variables

4.3.1. Scientific identity

Scientific identity was measured using a visual assessment previously validated by McDonald et al. (2019).[5] Participants were asked to *"Select the picture that best describes the current overlap of the image you have of yourself and the image of what a scientist is."* Participants were asked to select among a set of seven overlapping circles varying in the degree of overlap from 1 (*no overlap*) to 7 (*near complete overlap*). Higher values represented greater scientific identity. This measure is based on the very well-known Aron et al. (1992) measure, which has been used to measure other identities (Ahlqvist et al., 2013; Tropp & Wright, 2001).

4.3.2. Identity certainty

Certainty was assessed by asking participants about the certainty with which they held their scientific identity. Specifically, participants indicated their certainty in their identity by completing the following item: "How certain are you in the response you just gave?" (1 = "*Not at all certain*" to 9 = "*Extremely certain*"). This is an efficient way to assess certainty as indicated by prior research focused on assessing certainty in group identity fusion (Paredes et al., 2020) and certainty in other mental constructs unrelated to identity (e.g., Gur et al., 2021; Santos et al., 2019; Shoots-Reinhard et al., 2015; Vitriol et al., 2019).

4.4. Dependent variable

4.4.1. STEMM expressed interest

Participants had to answer one question about their general interest in STEMM fields. Specifically, participants were asked the following question: "*To me, a career in science, technology, engineering, mathematics or medicine is* (1 = *Boring*, 9 = *Interesting*)." Higher values represented more interest in STEMM fields. This question was equivalent to other efficient measures used in other domains to assess career orientation (Elo et al., 2003; Gogol et al., 2014; Kotz et al., 2013). Interest in STEMM fields is an important initial step to promoting STEMM career pathways (e.g., Aeschlimann et al., 2016; Dweck, 2002; Eccles, 2009; Lubinski & Benbow, 2006).

5. Results

The STEMM interest measure was submitted to a hierarchical regression analysis, with scientific identity (centered), certainty (centered), and the interaction term (i.e., Scientific Identity × Certainty) as the predicting variables. Main effects were interpreted in the first step and the two-way interaction in the second, final step (Cohen & Cohen, 1983).

Results showed a main effect of scientific identity on STEMM interest, $b = 0.356$, $t(499) = 6.193$, $p < .001$, 95% CI [0.253, 0.488], Cohen's $f^2 = 0.071$, such that greater scientific identity was associated with higher interest in STEMM fields. Results also showed a main effect of certainty on STEMM interest, $b = 0.347$, $t(499) = 5.070$, $p < .001$, 95% CI [0.213, 0.482], Cohen's $f^2 = 0.051$, such that greater certainty was associated with higher interest in STEMM fields.

Most importantly, a significant two-way interaction between identity and certainty depicted in Fig. 1 emerged, $b = 0.109$, $t(498) = 2.878$, $p = .004$, 95% CI [0.035, 0.184], Cohen's $f^2 = 0.017$. Specifically, among those reporting higher certainty (+1SD), scientific identity was positively associated with interest in STEMM fields, $b = 0.515$, $t(498) = 6.617$, $p < .001$, 95% CI [0.362, 0.668]. For those reporting lower certainty (-1SD), the relationship between scientific identity and STEMM interest, while remaining significant, was weaker, $b = 0.197$, $t(498) = 2.338$, $p = .020$, 95% CI [0.031, 0.363].

6. Discussion

The results of the pilot study showed that higher scientific identity was associated with expressing more interest in STEMM fields. This association between scientific identity and interest was further moderated by certainty. When participants reported being relatively more certain of their identity, higher scientific identity was associated with greater interest in STEMM fields than when participants reported being relatively less certain. These results are consistent with prior SVT research showing that considering metacognitions is useful for improving the predictive validity of numerous mental constructs. Although using only one item to measure certainty is not the most reliable approach to assess the construct, it is important to note that this single item was sufficient to produce the predicted effect in this study, as well as in previous research (Paredes et al., 2020; Santos et al., 2019). Therefore, although more items can increase the reliability of a measure, this single item proved to be an efficient and effective way of assessing certainty. Nonetheless, in the following studies, we used different operationalizations of certainty beyond this initial single-item measure.

As noted previously, metacognitive processes generally include two procedural stages: having metacognitive experience and metacognitive usage of those experiences. For individuals to take into consideration the certainty in their identity it is necessary to engage in the second stage of metacognitive usage. According to SVT, because consideration of certainty requires more cognitive effort at the time of behavior than consideration of identity alone, reliance on existing certainty is proposed to increase as the amount of thinking prior to determining action increases. For that reason, in the next study we included a measure of elaboration as a previously unexplored moderator of metacognition usage in this domain. Furthermore, as described next, the following study moved from expressions of interest to evaluating actual

[4] The sample was predominantly female, which is useful given the specific interest in the role of scientific identity among female students (e.g., Blickenstaff, 2005; Cheryan et al., 2017; Eccles, 2009;).

[5] The definition of identity provided by McDonald et al. (2019) revolves around the concept of how individuals perceive themselves as members of the "scientists' group," and how they feel that the members of that group (scientists) accept them as a member. Thus, they emphasize in their work the importance of the extent to which students see themselves as compatible with other scientists, especially the importance of the recognition from valued mentors when talking about scientific identity (see also, Carlone & Johnson, 2007; Hernandez et al., 2017).

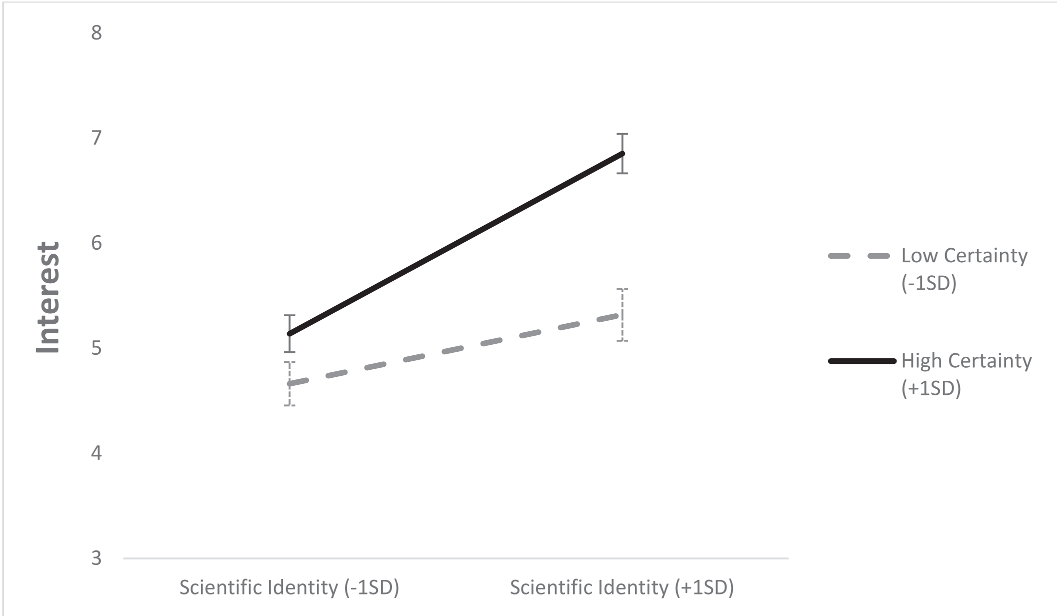

Fig. 1. Interest in STEMM fields as a function of scientific identity and certainty. Error bars show ± 1 SE.

performance in STEMM relevant tasks.

7. Study 1

The first study was designed to replicate and extend the results of the pilot study from expressed interest to actual performance. Therefore, this study was designed to examine whether scientific identity would be associated with performance in STEMM relevant tasks, and to what extent certainty could moderate the effects. Most relevant, a core goal of this study was testing for the first time the circumstances under which people are most likely to use (rely on) their existing identity-certainty to impact their behavior (i.e., engage in metacognitive usage).

Several changes were introduced. First, students were asked to complete a different measure of their scientific identity with more items (to enhance reliability), at the beginning of the study. Also, participants then were asked to answer two questions about their certainty (rather than just a single item). Next, participants completed a self-report measure of elaboration. Finally, instead of measuring interest, participants in this study were asked to complete a task designed to measure performance in an area potentially relevant to STEMM fields. Specifically, participants' performance on a mental rotation task served as the dependent measure.

First, we expected scientific identity to be predictive of performance on the mental rotation task. Second, we expected this association between identity and performance to be greater as identity-certainty was increased. Therefore, we expected to conceptually replicate the pilot study two-way interaction in which the greater the certainty in one's identity, the larger the correspondence between identity and performance. Finally, we expected to find evidence for the SVT prediction of a three-way interaction between scientific identity, certainty, and elaboration on performance. Specifically, we hypothesized that the moderating effect of certainty on identity-performance correspondence would be more likely to emerge for participants reporting higher elaboration. If correct, this three-way interaction would establish the extent of elaboration as an unexplored moderator of the impact of certainty on identity-performance correspondence.

7.1. Method

7.1.1. Participants and design

Six hundred and two undergraduates (521 females, 72 males, and 9 unidentified) participated anonymously in this study. The age of the participants ranged from 17 to 36 ($M_{age} = 19.55$, $SD = 1.68$). Measured identity about STEMM, certainty in identity, and reported elaboration were the predictor variables. STEMM performance in a mental rotation task served as the dependent variable. Our final sample size was determined by the number of participants that we were able to collect during the two weeks in which the study was posted (602 participants). This sample size provided 0.80 power to detect an interaction effect size of Cohen's $f^2 = 0.013$, an effect size that was smaller than the two-way Scientific Identity × Certainty interaction obtained in the pilot study.

7.1.2. Procedure

Participants were told that they were taking part in an experiment to validate materials for future research. First, participants were asked to complete a scale about their scientific identity. Next, they reported the certainty in their responses to the identity scale. Then, participants reported their extent of elaboration and completed a performance task potentially relevant for STEMM fields consisting of mental rotation of geometric figures. Finally, they were thanked, debriefed, and dismissed.

7.1.3. Predictors variables

7.1.3.1. Scientific identity. Students' scientific identity was assessed with a 5-item visual scale previously validated by McDonald et al. (2019). Participants were asked to "*Select the picture that best describes:* (1) *the current overlap of the image you have of yourself and the image of what a scientist is,* (2) *the extent to which your knowledge of STEMM concepts matches that of a scientist,* (3) *the extent to which your capacity to use STEMM skills in a public setting matches that of a scientist,* (4) *the extent to which you think others (such as your STEMM professors) see your identity as overlapping with a scientist,* and (5) *your level of identification with scientists as a group*." In all these questions participants had to select among a set of seven overlapping circles varying in the degree of overlap from 1 (*no overlap*) to 7 (*near complete overlap*). Item-ratings were highly correlated (α = 0.874), thus averaged to create a merged scientific identity index.

7.1.3.2. Identity certainty. To assess overall certainty participants rated their responses to the identity questions on two 9-point semantic differential scales anchored at *not at all* (1) and *extremely* (9) confident and certain. Responses to these items were highly intercorrelated. We averaged these ratings to form a single index of overall certainty for each participant, $r(600) = 0.757$, $p < .001$.

7.1.3.3. Extent of elaboration. Elaboration was assessed by asking participants to report their extent of thinking during the study. Specifically, participants responded to the following question: "*How much did you think during the course of this survey?*" Responses were provided on a 9-point scale anchored at "*low thinking*" (1) and "*high thinking*" (9). This measure provides an efficient assessment of subjective elaboration and previous research has shown that this brief self-report can be effective in discriminating participants who had engaged in relatively high and low thinking in particular contexts (Barden & Petty, 2008; Moreno et al., 2021; Petty et al., 2002). This single-item measure also correlates with actual (objective) elaboration (Barden & Petty, 2008; Petty, Cacioppo, & Schumann, 1983).[6]

7.1.4. Dependent variable: Performance in mental rotation

Participants were asked to complete the Vandenberg Mental Rotation Test (VMRT, Vandenberg & Kuse, 1978) which consists of twenty questions. Each question contained one target image and four alternative images. Of the four alternative images, only two were identical to the target. Participants must mentally rotate each item and choose the two images that were identical to the target. One point was given for each correct response for a maximum of 40 points (Casey et al., 1992). This measure was selected because spatial abilities are crucial cognitive skills that influence academic success in STEMM domains (Lubinski, 2010; Uttal et al., 2013; Wai et al., 2009). In fact, spatial abilities are utilized in a variety of daily tasks, including sporting activities (Jansen & Lehmann, 2013), as well as academic and environmental learning (e.g., Hegarty et al., 2006; Labate et al., 2014).

7.2. Results

Performance in the VMRT was submitted to a hierarchical regression analysis, with scientific identity (centered), certainty (centered), elaboration (centered) and the interaction terms as the predictor variables. Main effects were interpreted in the first step, two-way interactions in the second and the three-way interaction in third, final step (Cohen & Cohen, 1983).

The predicted two-way interaction between identity and certainty was significant, $b = 0.539$, $t(597) = 2.552$, $p = .011$, 95% CI: [0.124, 0.954], Cohen's $f^2 = 0.010$. This pattern revealed that for participants reporting higher certainty in their identity (+1SD) greater scientific identity tended to be associated with better performance, $b = 0.580$ $t(597) = 1.650$, $p = .099$, 95% CI: [0.037, 0.089], although this effect did not reach significance. For those reporting lower certainty in their identity (-1SD), $b = -0.859$ $t(597) = -1.871$, $p = .062$, 95% CI: [−1.761, 0.043] the tendency was in the opposite direction: greater scientific identity was associated with worse performance. The two-way interaction between identity and elaboration on performance was not significant, $b = -0.052$ $t(597) = -0.469$, $p = .639$, 95% CI: [−0.302, 0.186]. The same occurred with the interaction between certainty and elaboration on performance, $b = -0.188$ $t(597) = -1.798$, $p = .073$, 95% CI: [−0.393, 0.017].

More importantly, results revealed a three-way interaction between scientific identity, certainty, and elaboration on performance, $b = 0.208$, $t(594) = 2.261$, $p = .024$, 95% CI [0.027, 0.390], Cohen's $f^2 = 0.009$. As illustrated in Fig. 2, for participants reporting relatively higher extents of elaboration (+1SD), a significant two-way interaction between identity and certainty on performance emerged, $b = 1.128$, $t(594) = 3.137$, $p = .002$, 95% CI [0.422, 1.834]. Specifically, among those reporting higher certainty (+1SD), scientific identity was significantly associated with performance, $b = 1.346$, $t(594) = 1.997$, $p = .046$, 95% CI [0.022, 2.669]. For those reporting lower certainty (-1SD), the relationship between scientific identity and performance was significant, but in the opposite direction, $b = -1.664$, $t(594) = -2.344$, $p = .019$, 95% CI [−3.058, −0.270]. For participants reporting relatively lower extents of elaboration (-1SD), no interaction between identity and certainty on performance emerged, $b = 0.101$, $t(594) = 0.361$, $p = .718$, 95% CI [−0.448, 0.649].[7]

7.3. Discussion

Although there was no main effect of scientific identity on mental rotation in this particular sample, the predicted SVT interaction between identity and certainty on performance was significant. Therefore, Study 1 conceptually replicated the results obtained in the pilot study by showing that identity was better predictor of performance when held with higher certainty. Even more important, Study 1 showed for the first time that certainty predicted the correspondence between scientific identity and performance to a greater extent when participants reported having engaged in relatively higher extents of thinking. Thus, among participants who reported being more thoughtful, the ability of identity to predict performance was stronger for those who indicated relatively higher levels of certainty. This was not the case for those who reported being less thoughtful. This study introduced a new finding by specifying for whom identity certainty is more likely to be taken into consideration. An open question worth examining is whether we could replicate these findings using a more reliable and chronic measure of elaboration (individual differences in need for cognition, NC, Cacioppo & Petty, 1982), as well as another relevant outcome (i.e., career choice).

8. Study 2

This study aimed to replicate and extend the findings of Study 1, by including a more reliable measure of elaboration and making several important changes. Therefore, this study was designed to examine whether scientific identity would be associated with STEMM-related choices, and to what extent certainty could moderate the effects of scientific identity on such choices. Most relevant, a key goal of this study was further testing and conceptually replicating the circumstances under which people are more likely to use their identity-certainty (i.e., engage in metacognitive usage). In this second study, individual differences in NC served as a proxy to assess the extent of elaboration. Prior research has shown that individuals high in NC are more likely to think in a variety of situations and are also more likely to engage in metacognitive assessments (i.e., make judgments of certainty; Tormala et al., 2002; Tormala et al., 2006; see Cacioppo et al., 1996; Petty et al., 2009; for reviews), but prior research has not examined whether NC is related to using certainty in the domain of identity. That is, NC has been studied so far regarding the first metacognitive stage (the formation or experience of certainty), but it has not been examined explicitly for the proposed second metacognitive stage (usage of that certainty). Students in

[6] Although subjective and objective elaboration are usually linked, they can be measured with different assessments: Whereas objective elaboration can be assessed by counting the number of relevant thoughts listed, or assessing to what extent the thoughts listed reflect the merits of the information presented, subjective elaboration refers to a self-report measure of how much thinking people perceive they have done. Despite their link, objective elaboration and subjective elaboration can be separated empirically and conceptually (see Barden & Petty, 2008; Moreno et al., 2021).

[7] A significant main effect of certainty on performance was found under low elaboration conditions, $b = 0.955$, $t(594) = 2.461$, $p = .014$, 95% CI [0.193, 1.718], showing that greater certainty was associated with better performance.

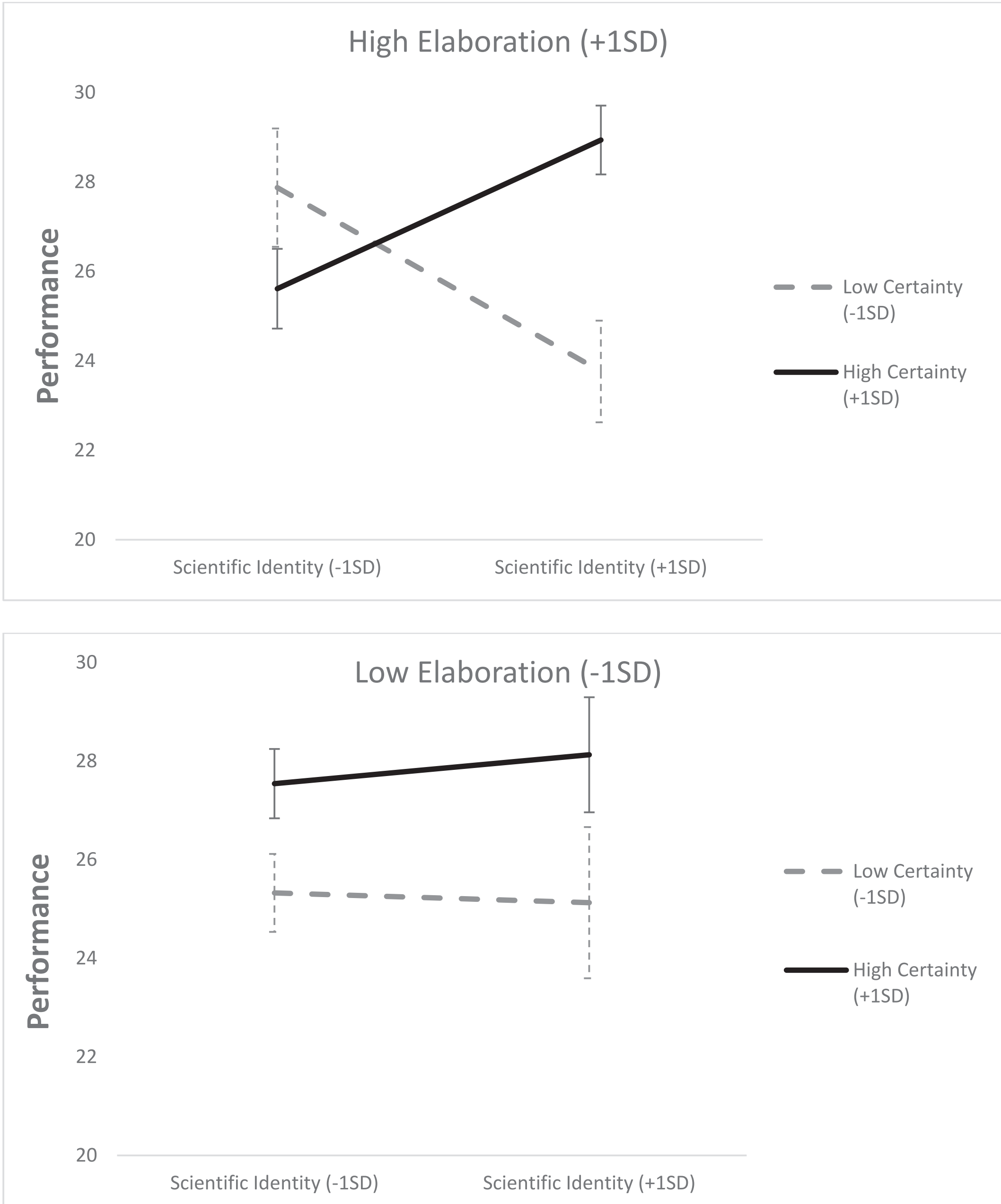

Fig. 2. Performance as a function of scientific identity and certainty for those reporting relatively high elaboration (top panel) and low elaboration (bottom panel). Error bars show ± 1 SE.

this study were first asked to complete a new measure of scientific identity. Then, they were also asked to rate how certain they were of their responses to that identity measure. Next, participants completed the NC measure (Cacioppo & Petty, 1982). Finally, participants indicated whether they were going to try out a STEMM-related field or not during the next year. This choice served as the dependent measure.

Despite these variations, we expected scientific identity to be associated with STEMM-related choice. Furthermore, we also predicted to find a two-way interaction between scientific identity and certainty on STEMM-related choice (i.e., the greater the certainty in one's identity, the greater relationship between that identity and STEMM-related choice). Most importantly, we also expected to find evidence of the SVT prediction of a three-way interaction between identity, certainty, and NC on making STEMM-related choices. Specifically, we hypothesized that the moderating effect of certainty on scientific identity-choice correspondence would be more likely to emerge as NC increased.

8.1. Method

8.1.1. Participants and design

Three hundred and twenty-eight undergraduates (280 females, 43 males, and 5 unidentified) participated anonymously in this study. The age of the participants ranged from 17 to 45 ($M_{age} = 19.52$, $SD = 2.16$). Measured scientific identity, the certainty associated with that measure, and NC were the predictor variables. STEMM-related choice served as the key dependent variable. Our final sample size was determined by the number of participants that we were able to collect during the two weeks in which the study was posted (328 participants). This sample size provided 0.80 power to detect an interaction effect size of Cohen's $f^2 = 0.024$. This was similar to the effect size of the Scientific Identity ×

Certainty interaction observed in the pilot study, but larger than the two- or three-way interactions observed in Study 1.[8]

8.1.2. Procedure

Participants were told that they were taking part in an experiment to test materials for future research. First, participants were asked to complete a scale assessing their scientific identity. Next, they reported the certainty in their responses to the identity scale. Then, they completed the NC scale. Finally, participants were asked to answer one question about their intentions regarding future STEMM career choices and were thanked, debriefed, and dismissed.

8.1.3. Predictors variables

8.1.3.1. Scientific identity. Students' scientific identity was assessed with a 5-item verbal version of the previously validated visual scale by McDonald et al. (2019) used in Study 1. Participants were asked to (1) "*What is the current overlap of the image you have of yourself and the image of what a scientist is?"* (from 1 *No overlap* to 7 *Near complete overlap*), (2) "*To what extent the knowledge of STEMM concepts you have matches that of a scientist?*" (from 1 *No match* to 7 *Near complete match*), (3) "*To what extent your capacity to use STEMM skills in a public setting match that of a scientist?*" (from 1 *No match* to 7 *Near complete match*), (4) "To what *extent you think others (such as your STEMM professors) see your identity as overlapping with scientist?*" (from 1 *No overlap* to 7 *Near complete overlap*), and (5) "*What is your level of identification with scientists as a group?*" (from 1 *No identification* to 7 Near complete *identification*). Item-ratings were highly correlated (α = 0.916), thus averaged to create a merged scientific identity index.

8.1.3.2. Identity certainty. To assess overall certainty in their identity, participants rated the certainty in their responses on the same two 9-point semantic differential scales used in Study 1. Item-ratings were highly correlated, $r(326) = 0.844$, $p \leq .001$, thus averaged to create a merged validity index.

8.1.3.3. Need for cognition. All participants completed the Spanish version of the 18-item Need for Cognition (NC; Cacioppo & Petty, 1982) scale (see Falces et al., 2001). It includes items such as "*I would prefer complex to simple problems*" and "*Thinking is not my idea of fun*" (reverse scored). Each item is answered on a 5-point Likert-type scale from 1 (*extremely uncharacteristic of me*) to 5 (*extremely characteristic of me*). Items were averaged to determine each participant's NC score. This trait measure assesses the tendency of individuals to engage in and enjoy effortful cognitive activities, which directly relates to their likelihood of elaborating on the information. Unlike the single-item measure of subjective elaboration, this measure is more reliable as it is designed to assess relatively stable individual differences (α =0.894). Importantly, this measure has shown excellent reliability and was found to be also valid to assess elaboration-related outcomes (e.g., predicting amount of thinking; see Petty et al., 2009; for a review).

8.1.4. Dependent variable: STEMM-related choice

Participants were asked to indicate whether they were going to try out a STEMM-related field or not during the next year (0 = *No;* 1 = *Yes*). This dichotomous measure was adapted from prior research (Kaleva et al., 2019). Promoting career choices in STEMM fields has shown potential to reduce gender and other sociocultural gaps (Wang & Degol, 2013, 2016).

[8] The limitation of being underpowered is addressed by an analysis of the collapsed data from the three main studies.

8.2. Results

The STEMM-related choice measure was submitted to a hierarchical logistic regression analysis, with scientific identity (centered), certainty (centered), NC (centered) and the interaction terms as the predicting variables. Main effects were interpreted in the first step, two-way interactions in the second and the three-way interaction in the third, final step (Cohen & Cohen, 1983).

Results showed a main effect of scientific identity, $b = 0.623$, $z = 5.338$, $p < .001$, 95% CI [0.393, 0.852], Cohen's $f^2 = 0.025$, such that greater scientific identity was more associated with choosing a career in STEMM-related fields. A main effect of NC also emerged, $b = 0.484$, $z = 2.123$, $p = .034$, 95% CI [0.037, 0.930], Cohen's $f^2 = 0.015$, with higher NC being associated with greater STEMM-related choice. The main effect of certainty did not reach significance, $b = 0.228$, $z = 1.875$, $p = .061$, 95% CI [−0.011, 0.467], Cohen's $f^2 = 0.010$. A significant two-way interaction between scientific identity and certainty on STEMM-related choices also emerged, $b = 0.316$, $z = 3.044$, $p = .002$, 95% CI [0.112, 0.519], Cohen's $f^2 = 0.012$. Specifically, among those with relatively higher certainty (+1SD), scientific identity was positively associated with STEMM-related choices, $b = 0.905$, $z = 5.386$, $p < .001$, 95% CI [0.576, 1.234]. However, for those reporting relatively lower certainty (-1SD), the relationship between identity and STEMM-relared choices did not reach significance, $b = 0.153$, $z = 0.823$, $p = .411$, 95% CI: [−2.112, 0.519]. Results also showed a non-significant two-way interaction between scientific identity and NC, $b = 0.155$, $z = 0.810$, $p = .418$, 95% CI [−0.220, 0.531], Cohen's $f^2 = 0.001$.

Most important, the regression revealed a three-way interaction between scientific identity, certainty, and NC on participants' STEMM-related choices, $b = 0.463$, $z = 2.268$, $p = .023$, 95% CI [0.063, 0.863], Cohen's $f^2 = 0.016$. As illustrated in Fig. 3 (top panel), for participants with relatively higher NC (+1SD), a significant two-way interaction between identity and certainty emerged, $b = 0.681$, $z = 3.712$, $p < .001$, 95% CI [0.322, 1.041]. Specifically, among those reporting higher certainty (+1SD), scientific identity was positively associated with STEMM-relared choices, $b = 1.429$, $z = 4.736$, $p < .001$, 95% CI [0.837, 2.021]. However, for those reporting lower certainty (-1SD), the relationship between scientific identity and STEMM-relared choices did not reach significance, $b = -0.194$, $z = -0.684$, $p = .494$, 95% CI [−0.750, 0.362]. As illustrated in Fig. 3 (bottom panel), for participants with relatively lower NC (-1SD), no interaction between identity and certainty emerged, $b = 0.101$, $z = 0.596$, $p = .551$, 95% CI [−0.231, 0.433].[9]

8.3. Discussion

Results of this study replicated the two-way interaction findings of the prior studies. That is, we replicated the interaction showing that scientific identity is a better predictor of STEMM-related choices when held with higher certainty. This finding extended that result to new materials, operationalizations, and dependent measures.

Beyond replicating the moderation by certainty, the results of this study also provided further evidence of the circumstances under which people are most likely to use their identity-certainty. Specifically, this study revealed that certainty predicted identity-behavior correspondence to a greater extent when thinking (as assessed with NC) was

[9] A non-significant main effect of scientific identity on STEMM-related behavior was found under low NC, $b = 0.345$, $z = 1.756$, $p = .079$, 95% CI [−0.040, 0.731]. This trend showed that more scientific identity tended to be associated with engaging in greater STEMM-related behavior. In addition, a significant main effect of certainty emerged, $b = 0.523$, $z = 2.656$, $p = .008$, 95% CI [0.137, 0.910], and participants reporting higher extents of certainty engaged in greater STEMM-related behavior than those reporting lower extents of certainty.

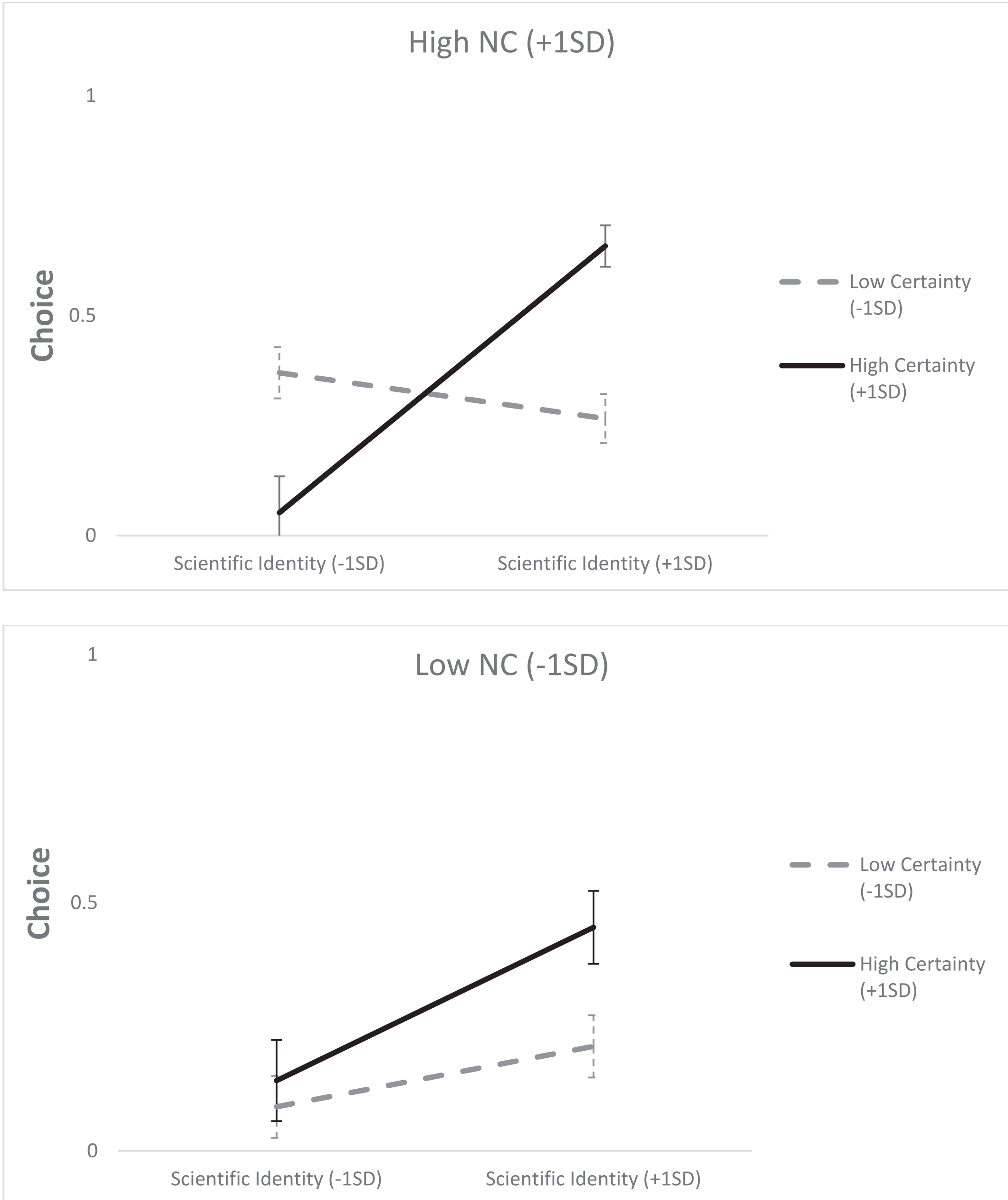

Fig. 3. Choice in a STEMM field as a function of scientific identity and certainty for those with relatively high NC (top panel) and low NC (bottom panel). Error bars show ± 1 SE.

relatively high. Thus, among participants who reported being higher in NC (and thus being more thoughtful in making decisions) the ability of identity to predict behavioral intentions became greater as identity certainty increased. This was not the case among those lower in NC.

Given that elaboration was assessed in Studies 1 and 2, the results obtained are potentially open to multiple interpretations. Perhaps most importantly, the self-report of elaboration (Study 1) and the individual differences in NC (Study 2) could be leading not only to the usage of certainty (as proposed) but also to the formation or experience of certainty. That is, these measures of elaboration could be affecting the first metacognitive stage rather than or in addition to the proposed second metacognitive stage (metacognitive use). Furthermore, there might be some confounding variables that co-vary with individuals' certainty and/or NC.

In order to deal with these potential interpretations, we moved to an experimental design in which both certainty and elaboration were manipulated within the same study. Even more relevant, elaboration will be manipulated in the next study *after* measuring identity and manipulating certainty but just before performance to isolate its impact at the time of the behavior. This change is especially important given that, as explained before, this research is designed to examine the role of elaboration on the second metacognitive stage focused on using (rather than experiencing) certainty.

9. Study 3

This study was designed to replicate and extend the findings of the previous studies but in this case by manipulating the two moderating variables: certainty and elaboration. Therefore, this study was designed to examine whether scientific identity would be associated with performance in STEMM relevant tasks, and to what extent manipulated certainty could moderate the effects of scientific identity on performance. More uniquely, the goal of this study was testing the circumstances under which people are most likely to use (rely on) their already formed certainty (i.e., engage in metacognitive usage). Thus, this final study introduced the manipulation of elaboration after certainty was formed. To do so, both an ability and a motivational based induction were combined. Importantly, in this study the manipulation of elaboration was designed to keep identity and certainty unaffected (since the elaboration induction came afterwards), while influencing participants' motivation and ability to think about their behavior prior to action. As described, these changes were introduced to examine the role of elaboration on the use of the already existing certainty (the main goal and novelty of the present research). In addition, this study measured scientific identity using both visual and verbal scales. Finally, Study 3 also aimed to generalize the results to a new outcome: performance in mathematics.

In sum, this final study introduced several important changes. First, participants were asked to report their scientific identity using both visual and verbal scales in combination. Although we did not expect differences between these two instruments assessing the same construct, we included both formats to gain further reliability and to replicate the findings of the previous studies within the same design. Then, as described in more detail below, certainty was manipulated (rather than measured as in the previous studies) to be relatively high or low. Therefore, both scientific identity and certainty were introduced in this study before varying elaboration. As noted, that is a critical aspect of this study designed to isolate the impact of certainty to the use stage. Finally, participants were asked to solve a math test consisting of 20 multiple-choice questions from the Graduate Record Examination (Jamieson et al., 2010; Moreno et al., 2022).

Despite these variations, we expected scientific identity to be associated with math performance. Second, we predicted this identity-performance effect would be especially likely to emerge when certainty was manipulated to be high rather than low. Even more relevant, we also predicted that manipulated elaboration would moderate the two-way interaction between identity and certainty on math performance. Specifically, we expected that the effect of induced certainty on identity-performance correspondence would be more likely to emerge for participants assigned to the high rather than low elaboration condition. Thus, a three-way interaction between scientific identity, manipulated certainty, and manipulated elaboration on math performance was hypothesized.

9.1. Method

9.1.1. Participants and design

Four hundred and thirty-eight undergraduates (371 females, 53 males, 2 non-binary and 12 unidentified) participated anonymously in this study in exchange for course credit. The age of the participants ranged from 16 to 48 ($M_{age} = 19.420$, $SD = 2.257$). Participants were randomly assigned to conditions in a 2 Certainty (High vs. Low) × 2 Elaboration (High vs. Low) design, with scientific identity as an additional continuous predictor. Math performance served as the dependent variable. Based on the effect size for the three-way interaction in prior studies (Cohen's $f^2 = 0.013$), results indicated that the desired sample size for a two-tailed test ($\alpha = 0.050$) with 0.80 power was $N = 606$ participants. Our final sample size was determined by the number of participants that we were able to collect before the end of the semester. Our final sample size (438) allowed us to detect an interaction effect size of Cohen's $f^2 = 0.018$.[10]

9.1.2. Procedure

Participants were told that they were taking part in an experiment to test some materials for future research. Then, they were asked to report their scientific identity using both visual and verbal scales. Again, we did not expect these two measures to differ. They were both included to have a more reliable assessment of the initial predicting variable. Next, certainty was manipulated to be relatively high or low. Specifically, participants were randomly assigned to either recall past episodes of confidence or past episodes of doubt. After this induction of certainty, elaboration was also manipulated. This manipulation of elaboration was designed to affect simultaneously participants' motivation and ability to think about their behavior during the performance task, without affecting previously measured identity and manipulated certainty. Afterwards, participants were asked to complete a math test consisting of 20 multiple-choice questions from the Graduate Record Examination (Educational Testing Service, 1999). The number of questions correctly answered served as the dependent measure. Participants completed socio-demographic questions, and were thanked, debriefed, and dismissed.

9.1.3. Predictor variables

9.1.3.1. Scientific identity. Students' scientific identity was assessed using both the visual and verbal scales used in the prior studies. Each of these instruments consisted of five items. The ten item-ratings were highly correlated ($\alpha = 0.942$), thus averaged to create a merged scientific identity index. We submitted this scientific identity score to a Confidence × Elaboration ANOVA to ensure that they were independent predictors. Results showed that identity did not vary as a function of induced confidence, $F(1, 434) = 0.939$, $p = .333$, or induced elaboration, $F(1, 434) = 2.340$, $p = .127$. The interaction term was not significant, $F(1, 434) = 0.028$, $p = .868$.

9.1.3.2. Identity certainty. Participants were randomly assigned to either a high or low certainty condition. In the high certainty condition, participants were asked to recall and describe a past personal episode in which they felt confidence. In the low certainty condition, participants were asked to recall and describe a past personal episode in which they felt doubt. Prior research has shown that this manipulation following a thought listing can lead people to misattribute the high or low certainty induced by the writing task to the mental content listed previously, even though this content is unrelated to the episodes described (Moreno et al., 2021; Petty et al., 2002; Requero et al., 2020). Because this induction came shortly after reporting on their scientific identity, it was expected to impact confidence in that identity, recently made salient.

9.1.3.3. Elaboration. Just before engaging in the performance task, participants were randomly assigned to either a high or low elaboration condition. Elaboration was manipulated by two simultaneous inductions of one based on personal relevance and the other based on cognitive load. Personal relevance is a determinant of motivation to think with higher relevance motivating more thinking (Blankenship & Wegener, 2008; Fleming & Petty, 2000; Petty & Cacioppo, 1990). Cognitive load is a variable that influences the ability or capacity to think with higher load reducing ability (Cacioppo & Petty, 1989; Ratneshwar & Chaiken, 1991). In the high elaboration condition, participants were told "*Your answers will be especially important given that the responses of relatively few people will be taken into account. Please, you should know that important decisions will be made based on your answers*" (high personal relevance). In addition, they were asked to memorize a short list of three single digit numbers (low mental load). In the low elaboration condition, participants were told that "*Your answers will be archived in a database along with those of so many other people. Please, you should know that your answers will be archived and might be or might not be taken into consideration*" (low personal relevance). In addition, they were asked to memorize a longer list of seven single digit numbers (high mental load). Participants were asked to rehearse the list of numbers in their mind at the time of

[10] Again, the potential limitation of being underpowered is addressed by conducting a collapsed data analysis from the three main studies.

behavior, and they were told that they would be asked to provide the numbers to the researcher at the end of the study. Similar inductions were used in prior research to manipulate participants' extent of thinking (e.g., Cancela et al., 2021; Kanfer & Ackerman, 1989; Liu et al., 2021; Petty et al., 1980). We used multiple elaboration inductions (mental load and relevance) at the same time to strengthen the manipulation (Kredentser et al., 2012; Tormala et al., 2002).[11]

9.1.4. Dependent variable: Performance in mathematics

Participants in this study were asked to solve 20 multiple-choice questions from the standardized math performance test of the Graduate Record Examination (Educational Testing Service, 1999). This math test consisted of 20 multiple-choice problems taken from the quantitative reasoning section of practice GREs (Jamieson & Harkins, 2009). This particular selection of 20 questions was successfully used previously by Moreno et al. (2022) in research testing the effects of thought valence on performance. The order of presentation of these questions was randomized and all participants responded to the same questions. Responses were coded as correct or incorrect (wrong answers, or no response), giving a minimum total correct score of 0 and a maximum of 20. The average number of questions solved was close to 10 ($M = 10.498$, $SD = 3.095$). Mathematical prowess is linked to scientific knowledge and the emergence of long-term dedication to scientific pursuits (Lubinski & Benbow, 2006).

9.2. Results

Performance in mathematics was submitted to a hierarchical regression analysis with scientific identity (centered), certainty (-1 = Low; 1 = High), elaboration (-1 = Low; 1 = High) and all their interaction terms as predictor variables. Main effects were interpreted in the first step of the regression, the two-way interaction in the second, and the three-way interaction in the final step (Cohen & Cohen, 1983).

Results showed a significant main effect of scientific identity on performance, $b = 0.284$, $t(434) = 2.096$, $p = .037$, 95% CI: [0.018, 0.551], Cohen's $f^2 = 0.010$, such that greater scientific identity was associated with greater performance. No other main effect reached significance, $ps \geq 0.802$. The two-way interaction between identity and certainty on performance was also significant, $b = 0.266$, $t(433) = 1.964$, $p = .050$, 95% CI: [0.000, 0.533], Cohen's $f^2 = 0.009$. This pattern revealed that scientific identity was a significant predictor of performance for participants assigned to the high certainty condition, $b = 0.576$ $t(433) = 2.867$, $p = .004$, 95% CI: [0.181, 0.971], but not for those assigned to the low certainty condition, $b = 0.044$ $t(433) = 0.241$, $p = .810$, 95% CI: [−0.315, 0.403]. The interaction between identity and elaboration on performance did not reach significance, $b = -0.145$, $t(433) = -1.067$, $p = .287$, 95% CI: [−0.411, 0.121], Cohen's $f^2 = 0.003$, nor did the interaction between certainty and elaboration, $b = -0.049$, $t(433) = -0.333$, $p = .740$, 95% CI: [−0.341, 0.242], Cohen's $f^2 = 0.001$.

More importantly, results showed a three-way interaction between scientific identity, certainty, and elaboration on performance, $b = 0.326$, $t(430) = 2.410$, $p = .016$, 95% CI [0.060, 0.592], Cohen's $f^2 = 0.013$.[12] As illustrated in Fig. 4 (top panel) for participants assigned to the *high elaboration condition*, a significant two-way interaction between identity and certainty on performance emerged, $b = 0.594$, $t(430) = 3.091$, $p = .002$, 95% CI [0.216, 0.971]. Specifically, among those assigned to the high certainty condition, scientific identity was significantly associated with performance, $b = 0.784$, $t(430) = 2.763$, $p = .006$, 95% CI [0.226, 1.341]. However, for those assigned to the low certainty condition, the relationship between scientific identity and performance was not significant and in the opposite direction, $b = -0.404$, $t(430) = -1.559$, $p = .120$, 95% CI [−0.913, 0.105]. For participants assigned to the *low elaboration condition* (Fig. 3, bottom panel), no interaction between identity and certainty on performance emerged, $b = -0.058$, $t(430) = -0.306$, $p = .760$, 95% CI [−0.433, 0.316].[13]

9.3. Discussion

Results of this final study produced evidence for scientific identity-performance correspondence in the domain of math performance. Using a manipulation (rather than a measure) of certainty, this study revealed that identity-performance correspondence was greater for those assigned to high (vs. low) certainty conditions. Importantly, Study 3 also replicated the effect of elaboration on the use of metacognition, this time manipulating (rather than measuring) the critical construct once certainty was already formed. Consistent with SVT predictions, the results of this study demonstrated that the effect of already existing certainty on identity-performance correspondence occurred only when elaboration at the time of behavior was manipulated to be high (vs. low). Importantly, we generalized such effects using different materials, measures and operationalizations and when identity and certainty were not affected by the elaboration induction.

10. General discussion

The results of these studies showed that scientific identity is a reliable predictor of relevant outcomes in the domain of STEMM fields. Although the concept of identity is multifaceted, it is worth mentioning that we used a validated measure of identity that varied in each of our studies (single pictorial item in the pilot, multiple pictorial items in Study 1, multiple verbal items in Study 2, and a combination of both pictorial and verbal items in Study 3), showing convergent results across these different assessments.

In addition, these studies showed that scientific identity was associated with behavioral outcomes (including performance and career choices) to a greater extent when participants were more certain of their scientific identity. We believe that this effect is novel in the field of scientific identity. This finding demonstrates that it is important to differentiate between merely holding a scientific identity and taking the certainty of that identity into consideration. The results regarding identity certainty are also consistent with SVT that postulates that the greater the perceived validity of any mental construct, the more consequential that mental construct becomes.

Even more uniquely, this research provided evidence for the conditions proposed by SVT that to enhance the likelihood of using metacognitions. Results supported the SVT prediction that the use of certainty to moderate scientific identity-behavior correspondence would be most apparent among those relatively high in their thinking at the time of the behavioral choice or action. Specifically, these studies showed that the effects of certainty were stronger for participants who reported having engaged in higher degrees of thought (Study 1), for participants who more chronically enjoy engaging in thinking (Study 2) and for those who were randomly assigned to high (vs. low) elaboration

[11] We don't expect differences in the results depending on whether participants' extent of elaboration is more induced by the capacity or by the relevance component of the manipulation.

[12] Only analyzing the items of the verbal scientific identity scale, the three-way interaction between scientific identity, certainty, and elaboration on performance was still significant, $b = 0.306$, $t(430) = 2.168$, $p = .031$, 95% CI [0.029, 0.582]. The three-way interaction was also significant when analyzing only the visual scale, $b = 0.295$, $t(430) = 2.438$, $p = .015$, 95% CI [0.057, 0.533].

[13] A significant main effect of scientific identity on performance was found under low elaboration conditions, $b = 0.430$, $t(232) = 2.280$, $p = .023$, 95% CI [0.059, 0.802], such that greater scientific identity was associated with greater performance. Therefore, scientific identity still predicted behavior under low elaboration conditions and the low elaboration induction did not eliminate every possible effect (just the usage of identity certainty).

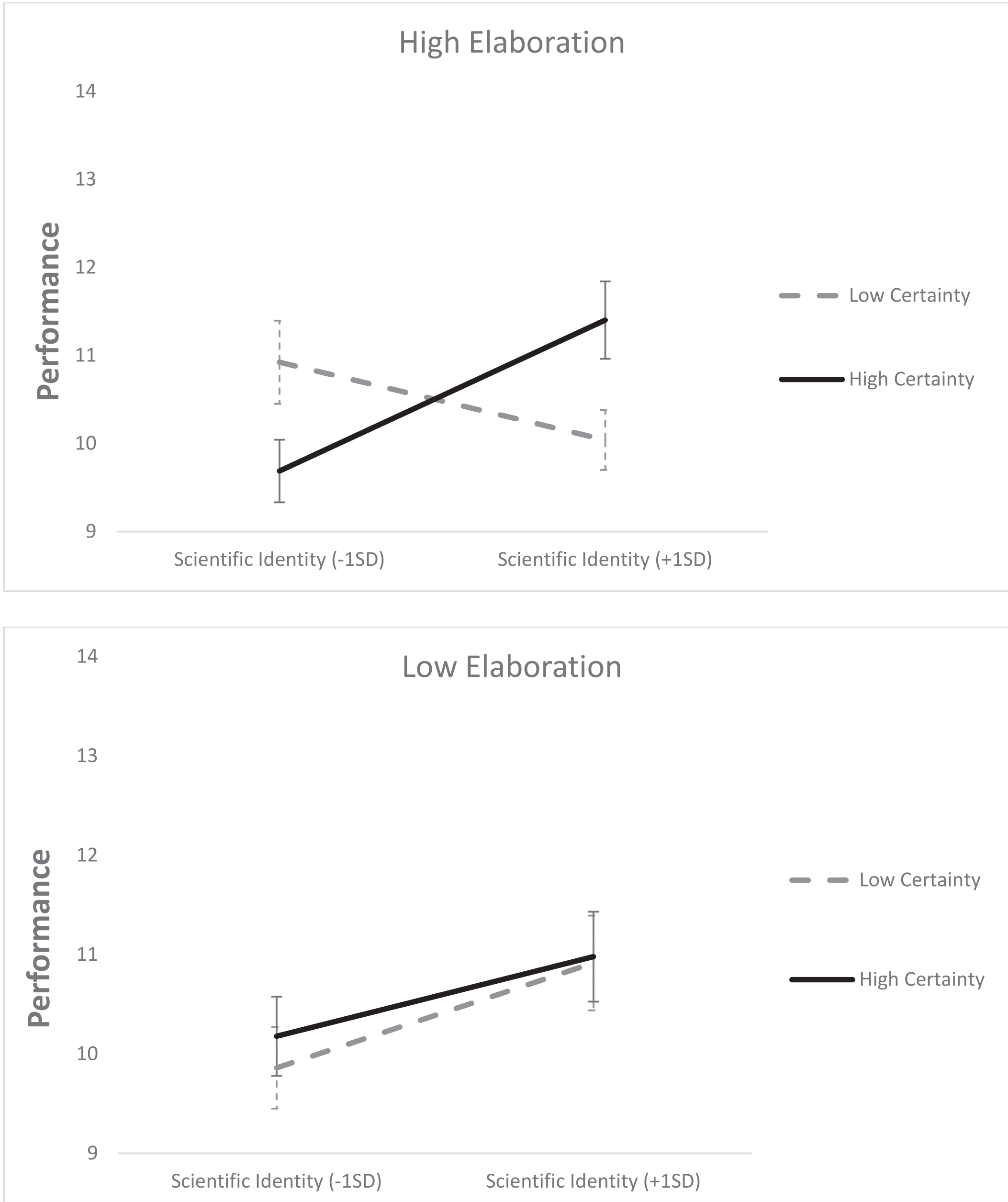

Fig. 4. Performance as a function of scientific identity and certainty for high (top panel) and low elaboration (bottom panel) conditions. Error bars show ± 1 SE.

conditions (Study 3). Also important, this research demonstrated that the predicted effect of elaboration moderating the use of certainty occurred regardless of whether certainty was measured or manipulated and whether elaboration was measured or manipulated after identity and certainty were already assessed. Therefore, the current studies suggest that relying on certainty is especially likely when the person or situation fosters relatively high thinking at the time of decision making or behavior. As noted, inducing elaboration after identity and certainty and just before behavior was the main innovation that served to manipulate amount of thinking without affecting scientific identity and certainty.

Despite the differences in the three methodological approaches to deal with elaboration (subjective elaboration, individual differences in NC, and manipulation of personal relevance and mental load), the results showed convergent evidence for this variable. In one study we assessed participants' perceptions of elaboration as a consequence of thinking but in other studies we assessed NC or manipulated motivation and ability which are antecedents of thinking. Using these different operationalizations of elaboration is a strength of the present research. Indeed, along with the multiple approaches to elaboration, the generalization of our findings to different outcomes (interest in STEMM fields, career choice, and performance in mental rotation and mathematics) is another strength of the present research making the contribution more generalizable.

In sum, thinking is not only important for generating perceptions of thought validity but also for taking those meta-cognitions into consideration. Study 3 of the present research manipulated the extent of thinking without influencing the experience or formation of certainty, showing that people were more likely to rely on identity certainty to guide identity-behavior correspondence when thinking was relatively high rather than low.[14] In conclusion, the current studies are relevant for understanding the conditions under scientific identity guides performance in STEMM relevant tasks such as mental rotation of geometrical figures and math, along with other important outcomes. Prior research had already determined that people can take their identities into consideration (e.g., I am scientist) before making decisions and before acting. Furthermore, prior research also showed that people can consider how certain they are in their mental constructs before engaging in behavior. The present research puts those two findings together in the domain of scientific identity and STEMM performance. Furthermore, the present research adds another key finding to this literature. Prior to the current research, it was not clear when people were more likely to take their identity certainty into consideration. Because certainty in one's scientific identity is so consequential, it becomes critical to understand when and for whom this metacognitive assessment is more likely to be taken into account. The present research takes an initial step in identifying a condition that enhances the use (rather than the formation) of identity certainty and highlights that understanding the metacognitive process of self-validation can help to improve prediction of performance based on scientific identity.

10.1. Future research

Future research could benefit from conducting more studies manipulating all relevant variables within the same experimental design. Certainty and elaboration were only manipulated simultaneously in Study 3 and more experimental studies would make these findings even more robust. Nevertheless, Study 3 yielded significant evidence regarding the predicted causal role of both certainty and elaboration. Also, this study showed this causal role using well-established experimental manipulations of each construct derived from previous research. Moreover, Study 3 was the third of a series, preceded by a pilot and two additional studies, all yielding convergent results regardless of all the variations and differences across studies. Consequently, when viewed collectively, given the consistency in the effects found for both manipulated and measured operationalizations of the variables and the absence of plausible alternative explanations (to our knowledge), we believe that Study 3 contributes to supporting a causal interpretation of the role of certainty and elaboration. Nonetheless, we acknowledge that future research could benefit from additional studies using further manipulations of certainty and elaboration simultaneously.

Beyond the methodological generalizations, future research could also benefit from conducting studies outside of the lab. We believe that the accessibility of scientific identity is likely to vary naturally among individuals and situations outside the lab and thus it is worth moving from the lab to real world contexts in follow-up research. Our studies demonstrates that identity can become accessible in contexts where it is relevant (e.g., when asked to complete a measure of scientific identity or a STEMM task). This aligns with findings from other research indicating that different identities can be situationally activated when encountering relevant stimuli (e.g., Ashforth & Mael, 1989; Markus & Kunda, 1986; Oyserman et al., 2012; Stryker & Burke, 2000). More uniquely, the novelty of the present research is that scientific identity can be activated along with other accompanying metacognitive processes. Thus, not only is identity activated when it is more likely to be relevant, but also the perceived validity of that identity (something that might or might not be taken into consideration, depending on the level of elaboration).

Although prior work has shown that metacognitive evaluations can make a significant difference outside the lab (DeMarree et al., 2020: Horcajo et al., 2019, 2024; Luttrell et al., 2020), it is critical to examine when and for whom metacognitions relevant to scientific identity are taken into consideration in real-world settings. Related to this point, future research could also benefit from investigating what happens when scientific identity is a central component of an individuals' overall identity. First, we might expect these individuals to be more likely to have a chronically activated scientific identity across situations since that identity is relevant to their self-concept. Thus, when scientific identity is highly relevant, such individuals might even take that identity into consideration when encountering tasks apparently unrelated to that identity. Second, because of its importance, these individuals might not only take their scientific identity into account in different situations, but also the associated certainty. That is, the relevance of that identity might increase elaboration, which in turn might make it more likely that certainty would also be taken into consideration. Finally, it is worth mentioning that changing the certainty associated with central identities through incidental inductions might be relatively more challenging compared to those with non-central identities.[15]

It is important to note that identity can be both activated and also taken into consideration when acting or making decision under low elaboration conditions, as indicated by the significant main effect observed in the collapsed dataset of the present research (see supplementary materials) where identity had an impact even under low elaboration. Future research could benefit from investigating this effect outside the lab as well. The present research points out that identity becomes even more predictive of relevant outcomes as certainty is also taken into account and, more uniquely, that subsequent identity certainty is more likely to be formed and then taken into consideration under high thinking conditions.

Finally, it is worth mentioning that our research reveals that the mere activation of identity and the mere activation of the associated certainty may not be sufficient to guide behavior; rather, it is their interaction with elaboration that provides a deeper understanding of how these two constructs enhance the prediction of behavior. In fact, the novelty of the present research is to introduce the idea that identity alone may not be sufficient to predict behavior if that identity is not also accompanied by a sense of certainty. And the impact of certainty is likely to be enhanced when people are motivated and able to take that certainty into consideration (which is something that requires thinking). As noted, identity scores were found to be more predictive of behavior as certainty increased but especially under high elaboration conditions. As mentioned previously, under low elaboration conditions we found either a main effect of identity or a main effect of certainty, but not the interaction effect. Therefore, the main point of the present research is that we discovered the conditions under which identity-certainty is more likely to be taken into consideration.

[14] To examine whether the three-way interaction observed in Studies 1–3 is further moderated by study or gender we combined the datasets of the three main studies and included these two additional predictors. As reported in the supplement the significant three-way interaction was not further moderated by study or gender (i.e., there were no four-way interactions, nor five-way interaction).

[15] Certainty, extremity and centrality are relevant constructs. Certainty refers to the perceived validity with which a mental content is held. It can be measured easily simply by asking people to rate how certain they are in any thought, in this case how confident they are in their responses to the identity scale (Paredes et al., 2020). Extremity indicates how far an individual's ratings deviate from neutrality in responding to a scale. Although extremity and certainty tend to correlate, one can be highly certain in neutral cognitions (DeMarree et al., 2015) and doubtful about extreme cognitions (Siev et al., 2023). Centrality refers to how critical and essential a particular dimension (in this case, scientific identity) is to an individual's overall self-concept. High centrality means this identity is a key, important part of their self-definition. As was the case for extremity, one can be certain in trivial identities and also be doubtful about highly important ones (Ashmore et al., 2004; Turner-Zwinkels & Brandt, 2023; Zunick et al., 2017).

10.2. Practical implications

This research can also help in designing better interventions, capable of producing actual changes in STEMM-related outcomes. Those potential interventions should consider that it is important not only to differentiate between merely holding a scientific identity and the validity associated with that mental content (i.e., identity-certainty), but also to consider the likelihood of taking that perceived validity into consideration before making a judgment or taking action.

The present research suggests that it may be possible to momentarily boost people's level of certainty to enhance the perceived validity of their scientific identity, thereby increasing the impact of that initial cognition on behavior. This supports the idea that people sometimes consult their initial cognitions and their confidence in those cognitions before acting (i.e., when thinking at the time of engaging in performance is relatively high).

As shown, rather than being inherently beneficial, certainty can magnify accessible mental contents. Therefore, for individuals starting with higher scientific identity, inducing certainty (as is proposed by many practical initiatives based on self-affirmation, empowerment, etc.) has benefits and can promote desired behaviors (e.g., better performance and greater engagement in careers related to STEMM fields, etc.). However, for individuals starting with lower scientific identity, those very same inductions of certainty can yield negative consequences (e.g., decreasing the occurrence of the desired outcome by enhancing the impact of low STEMM-identity). This research reveals that is especially the case under high-thinking conditions.

Similarly, doubts can reduce the impact of accessible mental contents, leading to positive or negative consequences depending on the person and the situation. For example, for individuals starting with lower levels of scientific identity, inducing doubts could have benefits and it can facilitate the achievement of desired consequences (e.g., better performance and greater engagement in careers related to STEMM fields, etc.). For individuals starting with higher levels of scientific identity, however, inducing doubts can backfire (e.g., decreasing the likelihood of the desired outcome), especially under high-thinking conditions.

Therefore, to design effective treatments, it is especially important to pay attention to the initial cognitions (high or low levels of scientific identity) to decide which kind of intervention (increasing certainty or doubts) is going to help more in producing the desired effects. As noted, for certainty or doubt to make a difference it has to be taken into consideration, which it is more likely under high thinking conditions as the present work reveals.

Open science practices

We report how we determined our sample size, all data exclusions, all manipulations, and all relevant measures in these studies (Simmons et al., 2012). Data and materials can be found on our OSF page (https://osf.io/jx89u/?view). All relevant measures and manipulations in these studies are reported. Finally, research was conducted in accordance with APA guidelines on the ethical treatment of human subjects. Permission to conduct this research was provided by the university institutional ethics committee before the studies began [UAM-CEI 104–2009; 31/01/2022].

CRediT authorship contribution statement

Lorena Moreno: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Pablo Briñol:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition. **Borja Paredes:** Writing – review & editing, Methodology, Investigation, Funding acquisition. **Richard E. Petty:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition.

Declaration of competing interest

We have no known conflict of interest to disclose.

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Appendix A. Supplementary data and materials

Supplementary data and materials for this article can be found online at https://doi.org/10.1016/j.jesp.2024.104663.

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