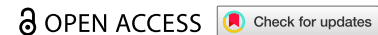


RESEARCH ARTICLE



An empirical ranking of the importance of the sources of self-efficacy for physical activity

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ABSTRACT

Background: While considerable research has centered on the concept of self-efficacy and its impact on behavior, relatively few studies have delved into the sources of self-efficacy beliefs. Bandura posited that the genesis of self-efficacy beliefs is based on the following four aspects: *personal experience*, *vicarious experience*, *verbal persuasion*, and *emotional state*. The objective of this research paper is to ascertain the relative importance of each source concerning self-efficacy for physical activity to determine whether some sources should be accorded with greater emphasis than others in future studies aiming to foster self-efficacy beliefs for physical activity.

Methods: An online study with 335 healthy German adults (162 men, 173 women) aged 18–68 was conducted. The sources of self-efficacy were compared by employing dominance analysis. This approach allows for the ordering of predictors according to their contribution to the explained variance, thereby providing more substantial insights and allowing for more concrete conclusions in comparison to the conventional multiple regression approach.

Results: As expected, *mastery experience* was shown to be the most important source of self-efficacy for physical activity, interestingly followed by *verbal self-persuasion* and *positive affective state*. Together, the sources of self-efficacy accounted for about 60% of the variance in self-efficacy.

Conclusions: Overall, understanding the etiology of self-efficacy is essential for developing effective and sustainable interventions to promote healthy behaviors. By focusing on the specific sources of self-efficacy that are most pertinent, interventions can be designed to be more effective.

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Introduction

Self-efficacy, referring to an individual's beliefs in their ability to perform a specific task or to achieve a goal, plays a pivotal role in influencing and modifying health behaviors (Bandura, 1997; Warner et al., 2020). Self-efficacy beliefs have been identified as a consistent predictor of subsequent health-related outcomes, including physical activity, healthy eating habits, smoking patterns, and alcohol consumption (Hevey et al., 1998). The relevance of self-efficacy has been shown to be consistent in research, as evidenced by recent publications, for example, by Choi et al. (2017) and Warner et al. (2020). Concerning physical activity behavior, which is strongly associated with health (OECD & World Health Organization, 2023), self-efficacy was frequently identified as the strongest predictor (Egele et al., 2025; Egele & Stark, 2024; Rovniak et al., 2002; Warner et al., 2011; Young et al., 2014), explaining the prominence of self-efficacy in psychological research.

As self-efficacy plays an instrumental role in multiple health behaviors, intervention studies frequently endeavor to enhance self-efficacy, as evidenced for example by the systematic reviews of Ashford et al. (2010) and Williams and French (2011). The preponderance of knowledge regarding the genesis of self-efficacy is rooted in Bandura's theoretical reasoning. According to Bandura's social cognitive theory (1997), self-efficacy is assumed to be shaped by four primary sources: *mastery experience*, *vicarious experience*,

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social persuasion, and *physiological and emotional states*. These sources influence an individual's perceived self-efficacy, which in turn impacts motivation, behavior, and performance. Additionally, the four sources in question are not assumed to be equal in terms of relevance. Bandura posits that mastery experience merits the greatest significance, followed by vicarious experience, verbal persuasion, and emotional arousal in descending order.

Mastery experience, derived from successfully navigating challenging situations through persistent effort, is assumed to represent the most potent source of self-efficacy (Bandura, 1997). These direct encounters with success bolster beliefs in one's capacity to execute similar tasks in the future. Conversely, failures, especially early on, can erode self-efficacy, particularly if attributed to a lack of ability. *Vicarious experience*, also referred to as social modeling, also serves as a pivotal conduit for the development of self-efficacy (Bandura, 1997). The observation of others' actions and the challenges they encounter facilitates the development of self-perception regarding one's capabilities. The impact of social modeling is amplified when the observed individual is perceived as similar in skills, abilities, or circumstances. The third source of self-efficacy, *verbal persuasion*, is defined as the encouragement, support, and feedback individuals receive from external sources (e.g. teachers, parents, coaches, peers) or through self-talk (Bandura, 1997). Positive affirmations have been shown to significantly bolster self-efficacy, particularly in individuals who harbor doubts about their abilities (Bandura, 1997). However, the effectiveness of verbal persuasion hinges on the credibility and trustworthiness of the source. For instance, feedback from a respected mentor is likely to carry more weight than encouragement from an individual perceived as less knowledgeable or authoritative. When the persuader is viewed as credible, individuals are more likely to internalize positive feedback and consequently strengthen their self-efficacy. Conversely, persuasion from an untrustworthy source has minimal impact. While positive verbal persuasion can significantly enhance self-efficacy, negative or unsupportive feedback can be detrimental. In addition to the valence of verbal persuasion, a distinction can be made between the actor and the recipient of persuasion: One can convince oneself or be convinced by others. Consequently, some authors have opted to differentiate between 'verbal self-persuasion' and 'verbal persuasion from others' (Warner et al., 2014). According to Bandura (1997), *physiological and emotional states* constitute the fourth source of self-efficacy. Individuals often interpret their physical and emotional reactions as indicators of their ability to perform a given task. For example, anxiety, tension, or fatigue may be interpreted as signs of inadequacy, leading to self-doubt and lower self-efficacy. Conversely, positive emotional states, such as calm or excitement, can bolster self-efficacy by signaling manageability. These physiological and emotional responses are frequently involuntary and subconscious, and individuals may be oblivious to their impact on perceived competence. Consequently, scholars have proposed a distinction in this regard and have advocated for the examination of positive and negative affect as discrete sources of self-efficacy (Warner et al., 2014).

It has been corroborated on several occasions that these factors serve as sources of self-efficacy. For example, evidence for the role of mastery experience in the formation of self-efficacy beliefs has been documented in previous research, where it was shown that the implementation of mastery experience in interventions constitutes a highly efficacious method for the augmentation of individuals' self-efficacy beliefs regarding physical activity engagement (Ashford et al., 2010; Parschau et al., 2013; Parschau et al., 2014; Wiedenman et al., 2024). In line with the theoretical considerations, empirical research has also shown that self-efficacy concerning physical activity can be enhanced through vicarious experience (Ashford et al., 2010; Kim et al., 2021; Rowland et al., 2020; Selzler et al., 2020). Research results concerning the effects of persuasion provide evidence for a positive relation between persuasion and physical activity behavior (Aldenaini et al., 2020) and self-efficacy for physical activity (Woodgate & Brawley, 2008). Additional research on the topic of self-talk has revealed that self-persuasion is a dependable catalyst for self-efficacy within a range of exercise disciplines (Galanis et al., 2016; Hardy et al., 2005). Research is scarce concerning the effects of positive or negative affective states on self-efficacy beliefs (Samson & Solmon, 2011), however, positive affect was found to explain levels of physical activity (Lawton et al., 2009; Rhodes et al., 2009; Whitehead, 2017). Additionally, systematic reviews comparing intervention techniques for changing physical activity conclude that targeting the sources of self-efficacy postulated by Bandura is a possible pathway to increasing self-efficacy (Ashford et al., 2010; Williams & French, 2011).

Although the sources have been demonstrated to be effective in influencing self-efficacy, there remains a debate on whether some sources of self-efficacy are more relevant than others. While Bandura proposed a theoretical hierarchy assuming that mastery experience should be the most important source, followed by vicarious experience and verbal persuasion (Bandura, 1997; Pajares, 1997). Schwarzer and Luszczynka (2022) ordered the importance of the four sources in the following order: mastery experience, vicarious experience, verbal persuasion, affective states. The tendency among researchers to impose a particular order upon the sources, despite the absence of empirical corroboration for such arrangements is noteworthy. Therefore, the importance of the sources of self-efficacy has to be substantiated through empirical evidence. This issue seems to be of particular relevance to the utilization of Bandura's sources of self-efficacy in intervention settings, as it would be advantageous to develop intervention studies predicated on the source of self-efficacy that is most adept at influencing self-efficacy.

Initial attempts have already been made to determine the importance of the sources empirically.

For instance, Williams and French (2011) and French et al. (2014) have conducted reviews to identify which intervention techniques are particularly effective in influencing self-efficacy and physical activity. Some intervention techniques can be loosely assigned to some sources of self-efficacy postulated by Bandura, but do not appear to be identical. Additionally, while a successful intervention may serve as an indicator that a source of self-efficacy influences self-efficacy, numerous additional factors may contribute to the efficacy of an intervention, such as the intervention's effectiveness and its alignment with the recipients' needs. As a result, it seems difficult to take these reviews as empirical evidence for an order of importance of Bandura's sources on the basis of these findings.

Other researchers took a different approach to determine the importance of the sources of self-efficacy empirically. For example, according to the findings of several prospective studies, mastery experience has been identified as the strongest source of self-efficacy for physical activity among older adults. Additionally, vicarious experience and somatic states were shown to have significant direct effects on self-efficacy (Warner et al., 2011), whereas all six sources of self-efficacy were shown to be directly related to self-efficacy, when assessed using validated scales (Warner et al., 2014). These studies employed a variable-centered approach, wherein self-efficacy was regressed on the sources of self-efficacy. Subsequently, the beta weights and their statistical significance were assessed, with the objective of ascertaining the 'strongest' source of self-efficacy. Nonetheless, the adequacy of this methodological approach in addressing the question of source importance is debatable. The fundamental premise of a regression analysis is to delineate the relationships between a dependent variable and multiple independent variables, with the objective of predicting the value of the dependent variable based on the values of the independent variables. The resulting regression coefficients quantify the impact of each independent variable on the dependent variable while partializing the effects of the other independent variables out. However, in the pursuit of identifying the predominant source of self-efficacy, the question is how large is the proportion of the explained variance that each predictor contributes to the total explained variance. It must be noted that the regression coefficients (neither unstandardized nor standardized) do not answer this question because they do not take into account the effects that arise due to the fact that the independent variables are generally related – in technical term: there are covariances between the predictors. However, these covariances between the predictors contribute their own share to the amount of total explained variance.

Therefore, it can be concluded that the issue of the importance of the different sources of self-efficacy remains unresolved by previous studies.

To address this issue, an alternative statistical technique is proposed: the application of relative importance analysis. In essence, the primary distinction between regression analysis and relative importance analysis lies in their respective focuses. Regression analysis prioritizes the modeling and prediction of outcomes, whereas relative importance analysis emphasizes the identification of the most influential predictors of a regression model by assessing the amount of explained variance that each predictor contributes to the total explained variance. The outcomes of regression analysis yield coefficients that quantify the relationship between variables, while relative importance analysis generates a ranking of variables based on their amount of contribution to the total explained variance. This distinction enables alternative interpretations of the results. Regression analysis aids in comprehending the direction and magnitude of effects with respect to prediction, while relative importance analysis facilitates the

identification of the most influential predictors in terms of their contribution to the explained variance. Consequently, the evaluation of the sources of self-efficacy by a relative importance analysis appears to be more suitable for addressing the question of how the different sources of self-efficacy contribute to the explanation of self-efficacy. To the best of our knowledge, however, this approach has not yet been applied so far, resulting in a notable research gap concerning the empirical tenability of the hierarchy of the sources of self-efficacy.

In consideration of Bandura's theoretical postulates and extant research findings, it can be hypothesized that mastery experience constitutes the most important source. Nevertheless, this is the sole hypothesis that can be reasonably accepted in the absence of consistent conclusions regarding the remaining three sources of self-efficacy, where Bandura's (2000) theoretical assumptions of vicarious experience being the second most important predictor contradict the findings of Warner et al. (2014) who found negative affective states and verbal self-persuasion to be significant sources of self-efficacy.

In light of these findings, the following study aimed to investigate the relative importance of the sources of physical activity-specific self-efficacy in greater detail and examine the relative importance of the sources of self-efficacy.

We hypothesize (1) that mastery experience is the most important source of self-efficacy for physical activity. In addition, we exploratively examine (2) the relative importance of vicarious experience, persuasion, and affect as sources of physical activity self-efficacy.

Method

Sample and procedure

The present study was conducted following local legislation and institutional requirements (The Ethics Committee of the Faculty of Human and Business Sciences of Saarland University, 24–32). Participants were recruited through the dissemination of posters in public spaces throughout Saarland, Germany. Additionally, the study was promoted through postings on groups and platforms, including the Saarland test subject platform. The study's inclusion criteria included individuals over the age of 18 who possessed fluency in German at a native speaker level and were not suffering from severe medical conditions or physical impairments that would preclude them from participating in the study's physical activity component. The participants did not receive financial compensation for their time or other forms of remuneration for their involvement in the survey. The study was conducted using the online survey platform SoSci Survey (Leiner, 2024). Informed consent was obtained from all participants before their participation, and they agreed to the data protection regulation. Following this, the participants' self-efficacy concerning physical activity was assessed, and finally, the sources of their self-efficacy were assessed. In this vein, we adhered to the recommendations of Warner et al. (2014), who suggested that enquiring sources of self-efficacy before assessing perceived self-efficacy may introduce a distortion in the latter. Participants who did not complete the survey due to early discontinuation of participation before answering items concerning all sources of self-efficacy ($n = 37$) or refusal to consent to the utilization of their data ($n = 1$) were excluded from the analyzes. The sample included 335 healthy German participants between the ages of 18 and 65 ($M = 35.11$, $SD = 12.94$). All participants who had completed the questionnaire were found to have no missing values. The mean age of the 173 female participants (51.6%) was 33.05 years ($SD = 12.66$), and the mean age of the 162 male participants (48.4%) was 37.30 years ($SD = 12.91$). A total of 46% of the study's participants reported being in a relationship. 26% of the participants in the study reported that they were either currently engaged in academic pursuits or undergoing specialized training. 78% of the subjects reported having obtained a high school diploma or a higher educational credential. 69% of the participants indicated that they were engaged in work activities that exceeded 20 h on a weekly basis. The totality of the participants reported their place of residence to be in Germany Table 1.

Instruments

Sources of Self-Efficacy for Physical Activity Scale (Warner et al., 2014) was utilized to assess *sources of self-efficacy*. This scale was meticulously developed to assess the sources of self-efficacy in German,

Table 1. Descriptive statistics of the latent variables.

Scale and items	Loading	SE	p
Self-efficacy for physical activity^a			
I am able to be physically active even when I have a lot to do at home.	0.827	0.031	$p \leq .001$
I am able to establish a routine of be physically active regularly.	0.769	0.034	$p \leq .001$
I am able to be physically active even when there are many things going on in my life.	0.778	0.032	$p \leq .001$
I am able to be physically active even though I have other time commitments.	0.777	0.032	$p \leq .001$
I am able to be physically active even though the weather is bad.	0.688	0.043	$p \leq .001$
Mastery experience^b			
I have mostly been successful in being physically active on a regular basis.	0.631	0.044	$p \leq .001$
Even if it turned out challenging at times, I have managed to remain active.	0.851	0.024	$p \leq .001$
It was never difficult for me to be physically active on a regular basis.	0.877	0.022	$p \leq .001$
Vicarious experience^b			
I model myself on people who are more active than I am.	0.723	0.048	$p \leq .001$
I feel more confident in being physically active if I can model myself on somebody else.	0.765	0.043	$p \leq .001$
I feel motivated to be active if I see people my age being active.	0.512	0.059	$p \leq .001$
Verbal persuasion by others^b			
Others encourage me to be physically active.	0.716	0.043	$p \leq .001$
Whenever I lack motivation to be physically active, others encourage me to be.	0.764	0.036	$p \leq .001$
The people who are important to me encourage me to resume physical activities when I have quit doing them.	0.659	0.047	$p \leq .001$
Self-persuasion^b			
Whenever I struggle to be motivated for physical activity, I tell myself that I can do it.	0.769	0.034	$p \leq .001$
I tell myself I can manage to be physically active on a regular basis.	0.873	0.018	$p \leq .001$
I motivate myself to be physically active on a regular basis.	0.723	0.035	$p \leq .001$
Negative affect^b			
Just before I start physical activities, I feel worn out	0.689	0.041	$p \leq .001$
Just before I start physical activities, I feel tired.	0.845	0.028	$p \leq .001$
Just before I start physical activities, I feel tense.	0.883	0.030	$p \leq .001$
Positive affect^a			
Just before I start physical activities, I feel energetic.	0.850	0.023	$p \leq .001$
Just before I start physical activities, I feel thrilled in anticipation.	0.888	0.017	$p \leq .001$
Just before I start physical activities, I feel strong.	0.817	0.024	$p \leq .001$

Note: ^a Items from Egele and Stark's (2024) subscale self-efficacy for physical activity.

^b Items from Warner et al. (2014) scale concerning the sources of self-efficacy.

comprising a total of 18 items with 3 items designated for assessment of each source of self-efficacy. The scale is based on a rating scale from 1 (strongly disagree) to 4 (strongly agree), and a mean was calculated for each subscale. The original items were utilized as is, with no alterations made to them. The psychometric properties of the scale were found to be satisfactory. The reliabilities of the subscales are reported in Table 2, the exact items (translated from German by Warner and colleagues) are displayed in Table 1.

The assessment of *self-efficacy* concerning physical activity was conducted using the set of five items from the German SCT Inventory for Physical Activity (Egele & Stark, 2024). This particular subscale of the inventory has been meticulously designed to evaluate self-efficacy specifically related to physical activity. The scale is based on a rating scale ranging from 'very little' (0) to 'very much' (10) and a mean was calculated for the five items. Again, the original items were utilized as is, with no alterations made to them. The reliability of the subscale is reported in Table 2, the exact items (translated from German) are displayed in Table 1.

The assessment of *demographics*, including gender and age, was conducted through the utilization of open-ended inquiries. Relationship status, educational level, employment status, and living country were assessed using a drop-down menu.

Statistical analysis

We applied structural equation modeling to investigate our research question. All calculations were done in R (R Core Team, 2020) using the packages lavaan (Rosseel, 2012) and semTools (Jorgensen et al., 2020). We used the MLM estimator with Satorra-Bentler-scaled χ^2 -test statistic and robust standard errors because some manifest variables had a skewed distribution. Since we used the MLM estimator, the robust versions of the fit indices will be reported.

For all analyzes, we use a nominal significance value of $\alpha = .05$.

Table 2. Means, variances, correlations, and omega reliabilities of the subscales.

	Mean	Variance	Reliability ^a	(1)	(2)	(3)	(4)	(5)	(6)
(1) Self-efficacy	6.444	1.908	.808						
(2) Mastery experience	2.430	0.567	.827	.695					
(3) Vicarious experience	3.022	0.681	.714	.255	.427				
(4) Verbal persuasion by others	2.583	0.635	.758	.180	.292	.634			
(5) Verbal self-persuasion	2.929	0.605	.836	.672	.812	.554	.392		
(6) Negative affective states	1.667	0.577	.855	-.514	-.354	-.126	.110	-.380	
(7) Positive affective states	2.724	0.711	.889	.633	.737	.526	.359	.763	-.540

^a Omega reliabilities are reported.

The analytic strategy consisted of two parts. In the first part, we scrutinized the appropriateness of the measurement model of the latent variables employing a confirmatory factor analysis (CFA) model. In the second part, we investigated the research question with a multiple regression model with latent variables.

In the first part, we set up a CFA model containing self-efficacy and all its sources in one model to investigate the appropriateness of the measurement models. Concerning self-efficacy, we modeled correlations of the measurement errors between the third and fourth, the third and fifth, and the fourth and fifth indicators. The model's fit was judged based on the criteria given in Schermelleh-Engel et al. (2003). Each model should at least show an acceptable fit ($p_{\chi^2} \geq .01$, $CFI \geq 0.90$, $SRMR \leq 0.10$, $RMSEA \leq 0.10$, $p_{RMSEA} \geq .01$) or, at best, a good model fit ($p_{\chi^2} \geq .05$, $CFI \geq .97$, $SRMR \leq .05$, $RMSEA \leq .05$, $p_{RMSEA} \geq .10$).

In the second part, we investigated our research question regarding the importance of the variances sources of using the latent multiple regression model depicted in Figure 1. Note that this model has the same fit as the CFA model from the preceding step the same way, as both models are saturated.

We used the relative importance analysis to investigate the relevance of the various sources of self-efficacy. Relative importance refers to assessing how much each predictor variable contributes to explaining the variance in the dependent variable. It indicates the proportional contribution of each predictor to the explained variance R^2 by considering its independent and partial effects (Johnson & LeBreton, 2004)¹. The direct effects correspond to the effects reflected in the regression coefficient. In contrast, the partial effects reflect the effects conveyed from one exogenous variable to another through their covariation. By considering both effect types, relative importance allows answering which predictor is more important in predicting self-efficacy by ordering them according to their proportional contribution to the explained variance. One way to determine relative importance is dominance analysis (Azen & Budescu, 2003; Budescu, 1993). In the dominance analysis approach, a predictor is more important than another predictor if its additional contributions to possible subset models are greater than the contribution of the other predictors. The additional contribution of a predictor is measured by the increase in R^2 resulting from adding the respective predictor to a subset model. A subset model is a model that contains a subset of the predictors of the whole model. When considering all possible subset models to which the respective predictor can be added, the average increase in R^2 is called the dominance measure (Gu, 2022). The dominance measure indicates a predictor share of the total explained variance, and the dominance measure's rank order indicates the relative importance. The sum of the dominance measure adds up to the model's explained variance. We used the approach and function provided by Gu (2022) to implement dominance analysis. Data is available upon reasonable request from the authors.

Results

Measurement model

The measurement model fits well with $\chi^2 = 265.465$, $df = 206$, $p = .003$, $CFI = 0.982$, $SRMR = 0.056$, $RMSEA = 0.033$, and $p_{RMSEA} = .997$. The χ^2 -test statistic and the SRMR hint at an at least acceptable model fit according to the criteria mentioned above, whereas all the other fit indices point to a good model fit.

In particular, the modeled measurement correlations between the third and fourth (.700), the third and fifth (.380), and the fourth and fifth (.435) indicators of self-efficacy were significant (all $p \leq .001$), supporting our a priori assumptions about the error correlations. Table 1 reports the descriptive statistics of the latent variables, the latent variables' omega reliabilities are reported in the correlation table. Table 2

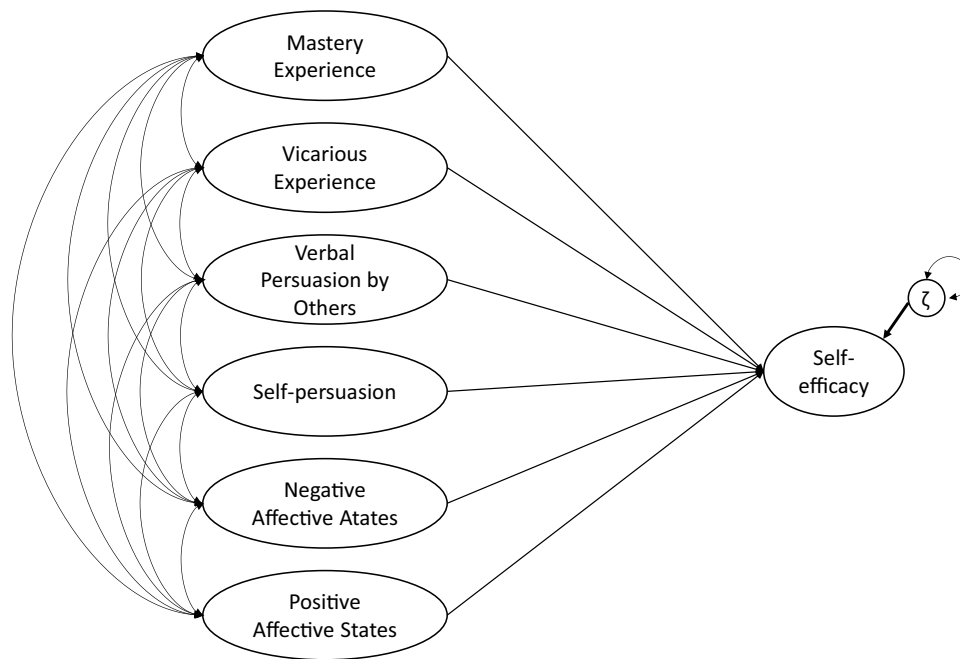


Figure 1. Latent multiple regression model. Alt Text: The figure illustrates the latent multiple regression model, in which self-efficacy is regressed on the six sources of self-efficacy.

reports the measurement model's standardized factor loadings. Descriptive statistics for the manifest variables can be found in the supplemental material.

Latent regression and relative importance analysis

Table 3 reports the results of the latent regression and relative importance analysis. The sources explained $R^2 = .559$ percent of the variance of self-efficacy in the latent regression model. Significant predictors were *Mastery Experience*, *Vicarious Experience*, *Verbal Self-Persuasion*, and *Negative Affective States*. With respect to *Vicarious Experience*, there is a change of sign between the positive bivariate correlation between *Vicarious Experience* and *Self-efficacy* and the negative path coefficient between *Vicarious Experience* and *Self-Efficacy*, indicating that the contribution of *Vicarious Experience* to *Self-Efficacy* decreases if the other sources are controlled for.

Concerning the dominance measures, the rank order of the predictors was *Mastery Experience*, *Verbal Self-Persuasion*, *Positive Affective States*, *Negative Affective States*, *Vicarious Experience*, and *Verbal Persuasion by Others*. Notably, *Positive Affective States* is the third most important predictor, but its regression coefficient failed statistical significance.

Discussion

This study aimed to gain a more nuanced understanding of the sources of self-efficacy and their importance for physical activity specific-self-efficacy beliefs. Together, the sources of self-efficacy accounted for approximately 56% of the variance in physical activity specific-self-efficacy. The rank order of relative importance of the sources was found to be *Mastery Experience*, *Verbal Self-Persuasion*, *Positive Affective States*, *Negative Affective States*, *Vicarious Experience*, and *Verbal Persuasion by Others*.

Although Warner et al. (2014) found all six sources of self-efficacy to be significant predictors of self-efficacy, findings of the current study revealed that only four of the six sources contributed significantly to explaining the variance – all except *positive affective state* and *verbal persuasion by others*. It seems important to acknowledge the potential influence of the sample size on the significance of a predictor in a multiple regression model. The test power of the current study may have been inadequate to detect a small

Table 3. Regression analysis and relative importance analysis.

	Estimate	SE	p	Std. estimate	DW
Mastery Experience	1.280	0.383	.001	0.381	0.184
Vicarious Experience	-0.503	0.256	.049	-0.180	0.023
Verbal Persuasion by Others	0.251	0.250	.316	0.084	0.010
Verbal Self-Persuasion	0.904	0.434	.037	0.287	0.158
Negative Affective States	-0.912	0.263	.001	-0.276	0.107
Positive Affective States	0.133	0.309	.666	0.050	0.118

Note. Estimate: regression coefficient. Std. Estimate: standardized regression coefficients. DW: dominance weight. Significant regression weights and important dominance measures are marked in bold.

to medium effect, which could have resulted in an inaccurate assessment of the predictor's significance. Similarly, it is conceivable that the relatively strong relationships between the different sources of self-efficacy (particularly in the case of *positive affective states*) influenced the resulting coefficients. Especially the finding that *positive affective states* – the third most important predictor and a contributor of approximately 12% to the explained variance of physical activity specific-self-efficacy – was non-significant, was unexpected. Due to the absence of adequate preliminary findings for the purpose of power calculation, the question remains whether there was an absence of significant correlation or whether it could just not be demonstrated. Nevertheless, a discrepancy between the results of the multiple regression and the dominance analysis would be explicable, as the regression coefficients represent the *direct* effect of a source on self-efficacy, not accounting for its *partial* effects, i.e. the effects conveyed from one exogenous variable to another through their covariation. In contrast, dominance analysis takes these indirect effects into account. Due to this conceptual difference, the results from both analyzes can diverge. Therefore, the concept of relative importance seems to be the more inclusive view of the role of the various sources of self-efficacy. However, there is a need to establish a threshold for the relative importance that demarcates the point at which a predictor is deemed important. For the current study, a threshold of about 10% explained variance would be plausible based on the dominance measures. Applying this threshold, *mastery experience*, *verbal self-persuasion*, *positive affective states*, and *negative affective states* would be important predictors of self-efficacy. It is, however, important to acknowledge that this threshold was established in an entirely arbitrary manner by the authors and is not based on any prior recommendations documented in extant literature due to an absence of such recommendations. Concomitant with this determination, other researchers may opt to set an alternate limit, which may result in divergent conclusions.

Taken individually, our findings align with Bandura's (1997) literature-based assumptions and empirical evidence from Warner et al. (2011, 2014) and other researchers, which indicate that mastery experience is the predominant source of self-efficacy. Our results support previous research and provide an initial indication that interventions to increase physical activity specific-self-efficacy - of which there is evidence that they can be effective (e.g. by French et al., 2014; Williams & French, 2011) – may be even more effective if they are based on mastery experience. This finding therefore doesn't seem noteworthy due to its novelty, but because of its alignment with prior studies. Intervention studies are associated with significant costs and effort, and as such, they ought to be designed as effectively and efficiently as possible. The coherence of our findings concerning the importance of mastery experience with previous findings supports the idea that the promotion of *mastery experience* might be given priority over other sources of self-efficacy. However, the findings of this study should not be misinterpreted in the sense that mastery experience represent the only important source of self-efficacy and, consequently, the sole meaningful starting point for interventions. Instead, three additional sources of self-efficacy were shown to be also of considerable importance.

Contrary to Bandura's assumptions but consistent with the findings of Warner et al. (2014), *verbal self-persuasion* was identified as the second most significant predictor. A potential discrepancy may emerge between our study's findings and Bandura's assumptions, particularly in light of a methodological divergence concerning the conceptualization of persuasion. While Bandura's theoretical framework positions persuasion as a holistic construct, our research draws on the introduction of a nuanced distinction between self-persuasion and persuasion by others as proposed by Warner et al. (2014). Our findings indicate that *verbal self-persuasion* emerges as an important contributor. Conversely, the influence of *persuasion by others* appears to be comparatively negligible. These findings suggest that an

undifferentiated perspective on this source of physical activity specific-self-efficacy might lead to an underestimation of its overall relevance. Consequently, our findings offer a valuable contribution to future research by underscoring the importance of differentiating between self-persuasion and persuasion by others as our results suggest that such a differentiation would be an important avenue for future exploration.

The third most important source of physical activity specific-self-efficacy was found to be *affective states*. Although Schwarzer and Luszczynska (2022) hypothesized that affect would have the least impact on self-efficacy, the present results do not substantiate this conclusion. Nonetheless, as Bandura has posited, the role of affect as a source of self-efficacy may be domain-specific (Bandura, 1997), and he suggested that affective states may be especially pertinent to exercise behavior (Bandura, 1997). This assumption would be in alignment with our empirical findings. It is interesting to note that, aligned with the findings of Warner et al. (2014), *positive affective states* was the third most important source in our dominance analysis, followed by *negative affective states* as also reported by Warner et al. (2014).

In our study, *vicarious experience* and *persuasion by others* were the least important sources of physical activity specific-self-efficacy. However, once more, the results of the regression analysis and the results of the dominance analysis contradict each other: whereas *vicarious experience* seems to be a significant negative source of self-efficacy, it does not seem important for the variance explained in self-efficacy. Although the bivariate correlation of vicarious experience with self-efficacy was positive, the partial correlation in the multiple regression model was negative. This can be attributed to the incorporation of the alternative sources of self-efficacy in the multiple regression model. As correlation coefficients are related to the partial correlations, the partializing out of these additional sources of physical activity specific self-efficacy leads to the negative regression coefficient of self-efficacy on vicarious experience. It seems like when also considering the contributions of the additional sources, vicarious experience becomes comparatively less impactful and is superseded by the influence of these other sources. Warner et al. (2014) found a significant positive relation between *vicarious experience* and self-efficacy in their multiple regression model. The difference of direction in the multiple regression model might be attributed to the fact that Warner and colleagues' research focused on older subjects, while the subjects in the present study were younger and reported an above-average level of activity. Therefore, it might be hypothesized that vicarious experience is more significant in contexts where physical activity levels are lower. It would also be conceivable that vicarious experiences play a particularly important role in the context of self-efficacy for the initial stages of a behavior, e.g. initiating or learning a new behavior, but less in the context of self-efficacy in relation to habitual, regular behaviors, which was the focus in this study. The absence or negative direction of the relation has also been shown in other domains, such as learning, where *vicarious experience* has been shown to exhibit a mildly negative effect on self-efficacy (Sheu et al., 2018). However, this finding appears to contradict Bandura's theoretical assumptions. The question arises as to why Bandura ascribed such significance to vicarious experience if their relevance remains unsupported by empirical evidence. It is possible that Bandura's Social Learning Theory (1977) influenced his perception of the hierarchy of the sources of self-efficacy. According to the principles of social learning theory, vicarious experience may exert an influence on an individual's behavior. It is conceivable, however, that vicarious experience exerts an influence on behavior, though not necessarily on self-efficacy. This assumption is supported by the findings of Warner et al. (2014), who observed no indirect effect of vicarious experience via self-efficacy on behavior but a significant direct effect of vicarious experience on behavior.

A discrepancy between our results and Bandura's assumptions was also evident in the context of verbal persuasion by others, as verbal persuasion by others was not found to be an important source of physical activity-specific self-efficacy. It is conceivable that verbal persuasion exerts an influence on action without necessarily affecting self-efficacy. This was shown by Warner et al. (2014), as the indirect effect of verbal persuasion by others via self-efficacy on behavior was not significant, but the direct effect of vicarious experience on behavior was. This could occur, for instance, through the perception of verbal persuasion as a social norm, or facilitator (Ajzen, 1991).

Future studies could adopt this as a point of departure and examine the extent to which the presumed sources of self-efficacy exert an indirect influence on behavior via self-efficacy or to which they manifest themselves as largely independent from self-efficacy. This would imply that these factors should not be regarded as sources of self-efficacy in a strict sense but rather as influencing factors in addition to

self-efficacy. This line of inquiry also prompts the question of how these additional factors might be integrated into social-cognitive theory, the theoretical foundation from which self-efficacy is derived.

Consequently, one might conclude that Bandura's hierarchy of sources of self-efficacy appears to be relatively adequate. The hierarchy proposed by Bandura, except for vicarious experience, remains consistent, comprising *mastery experience*, *verbal self-persuasion*, and *affective states*.

In addition to addressing the individual sources of self-efficacy, a holistic approach can also be considered: Taken together, *mastery experience*, as well as *verbal self-persuasion*, and *affective states*, both positive and negative, appear to be of significant importance. This is what Joët et al. (2011) refer to as 'direct experience' in their meta-analysis. The authors have demonstrated in another domain (learning) that these personal experiences taken together served as a more powerful predictor of self-efficacy than vicarious experience. Given the domain-specific nature of self-efficacy and the potential risks of transferring results and findings from one domain to another without careful evaluation, it still seems viable to synthesize ideas across different domains if analogous findings are identified. Therefore, in consideration of our findings, it can be posited that concerning self-efficacy for physical activity, the so called 'direct experiences' are more important for self-efficacy than vicarious experience.

In light of the findings presented, we propose that future studies prioritize the exploration and fostering of personal experiences, which appear to be the most important source of physical activity specific-self-efficacy. Additionally, our findings in concert with previous research suggest that this phenomenon is robust across various domains and evaluation methods. More generally, we would recommend prioritizing direct experience as opposed to vicarious experience, as vicarious experience seemed rather unimportant for the variance in physical activity specific-self-efficacy in our study. This prompts further inquiry into how these direct experiences are interconnected, and the extent to which they are mutually dependent or exert influence on each other. Consequently, the emphasis should shift from the evaluation of the hierarchy of the individual sources to a more comprehensive investigation of their interplay, as attempted by Huang et al. (2020), for example.

Limitations

It is imperative to underscore that the focal point of this study was exclusively on physical activity-specific self-efficacy. The sources of self-efficacy were inquired about specifically in relation to physical activity behavior, and the self-efficacy scale also referred explicitly to physical activity-specific self-efficacy. Consequently, the transfer and generalizability of results to other domains is precluded until such replication occurs.

Additionally, the items concerning physical activity-specific self-efficacy focus on the self-efficacy to be physically active despite obstacles and not the self-efficacy related to specific skills. Consequently, the present study does not examine the conviction of being able to be active in principle, such as taking the stairs instead of the elevator. Therefore, the sources of self-efficacy and our tentative recommendations for intervention approaches based on the relatively important sources do not refer to the self-efficacy beliefs in the sole ability, but rather the self-efficacy beliefs in the ability to perform a behavior despite challenges. This lends our study a certain external relevance, as the self-efficacy of being able to be physically active despite challenges appears to be much more central to reducing the lack of physical activity prevalent worldwide than the self-efficacy of being able to demonstrate a certain skill.

However, in light of the inconclusive role of vicarious experiences, a notable limitation of this study is its exclusive emphasis on the impact of sources on physical activity specific-self-efficacy. A more comprehensive exploration of the importance of the sources of self-efficacy might call for embedding the sources within a comprehensive social cognitive theory framework. Additionally, the present study examined the importance of sources in the sample as a whole, employing a variable-centered approach. There is, however, evidence suggesting inter-individual variations in the sources of self-efficacy, which could be concomitant with the phenomenon that the hierarchy of sources is not universally tenable for all individuals. Consequently, a dominance analysis could be conducted for specific subpopulations (e.g. gender, possible gender differences were reported by Chen et al. (2023), for example), or a person-centered approach could be considered, in which inter-individual differences in the sources of self-efficacy are taken into account. This would especially be beneficiary as the findings of this study are based on a WEIRD

convenience sample (western, educated, industrialized, rich, and democratic). Although this approach is very common in psychological research (Nielsen et al., 2017), it limits the generalizability of the research results. Additionally, the subjects of our study were, on average, younger than the typical German population and they reported higher levels of physical activity compared to the average German population. As such, the findings of this study should probably be interpreted cautiously and we would advocate for the replication of this study in a more heterogeneous setting. This limitation may also reveal new research questions to be explored in future studies. For example, it could be investigated whether the importance of sources of physical activity specific-self-efficacy remains stable or develops across different age groups. An additional investigative element would be to determine whether the hierarchy of sources remains constant across the varying levels of physical activity specific-self-efficacy and physical activity.

However, it is important to note that the findings of this study are predicated exclusively on cross-sectional analyzes with the aim to determine the relative importance of the sources of self-efficacy for physical activity. Consequently, it might be fruitful to integrate the three distinct approaches to determining the importance of sources of self-efficacy – those of French et al. (2014), Warner et al. (2011, 2014), and the present study – to establish a comprehensive foundation for future research.

Conclusion

In the present study, the importance of the sources of physical activity specific-self-efficacy was examined using dominance analysis. As expected, *mastery experience* was shown to be the most important source of self-efficacy, followed by *verbal self-persuasion* and *positive affective state*. By focusing on the specific sources of self-efficacy that are most pertinent, interventions might be designed to be more effective and health can be improved more systematically. Based on the findings of this study, interventions aiming at fostering physical activity specific-self-efficacy should primarily focus on personal experience rather than vicarious experience, although the role of vicarious experience will need to be explored further.

Author contributions

VSE: Conceptualization, Methodology, Investigation, Data Curation, Validation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project Administration.

EK: Conceptualization, Methodology, Formal Analysis, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization.

RS: Writing – Review & Editing, Supervision.

Endnotes

- ¹ Relative importance analysis was initially developed by Pratt (1987) and further developed by Budescu (1993), Johnson (2000), and Lipovetsky and Conklin (2001). For an overview of the history of relative importance analysis see Johnson and LeBreton (2004).

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Data availability statement

Data is available upon reasonable request.

Informed consent

Written informed consent was obtained from all participants before their participation in the study.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by an Ethics committee. See details under Methods.

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