

**AUTOMATIC AFFECTIVE REACTIONS
TO EXERCISE-RELATED STIMULI**

Towards a Better Understanding of Exercise Motivation

by

Michaela Schinköth

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Prof. Dr. Zachary Zenko

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1 Preface

This thesis contains the synopsis of my dissertation, as required by the Faculty of Human Sciences at the University of Potsdam. The dissertation, which consists of three publications, is based on research conducted at the Department of Sport and Health Sciences, Sport and Exercise Psychology, University of Potsdam. The publications are briefly described and the main results are summarized. This thesis presents a framework for the relationship between the publications and elaborates the conceptual considerations that led to the three publications. Finally, methodical and theoretical implications are discussed.

2 Automatic affective reactions to exercise: Outline of the research program

Why do so many individuals struggle to achieve the recommended amount of exercise? It may be that the mere thought of exercising makes them feel uncomfortable. Research on the role of automaticity and affect in exercise motivation has flourished in recent years (Ekkekakis & Dafermos, 2012; Rhodes, McEwan, & Rebar, 2019; Rhodes & Kates, 2015). Referring to dual-process theorizing (e.g., Strack & Deutsch, 2004; Gawronski & Bodenhausen, 2006; Evans & Stanovich, 2013), behavioral motivation is not solely based on rational reflections (e.g., about perceived self-efficacy or outcome expectations) but is also driven by automatic affective processes.

This thesis focuses on the affective–reflective theory of physical inactivity and exercise (ART; Brand & Ekkekakis, 2018), a dual-process theory developed to explain the motivational processes underlying the initiation of exercise-related behaviors. The ART emphasizes how a momentary, automatic affective reaction to reminders of exercise (type-1 process) can directly impact exercise-related decisions. This affective reaction then creates the foundation for a more reflective, rational motivational process (type-2 process). Negative feelings that are automatically activated by the thought of exercise can act as a restraining force that leads an individual to remain inactive. Considering the behavioral influence of this automatic affective reaction is an innovative approach in exercise psychology research and may help explain why some individuals do not exercise, even though they are aware that exercising would be a “rational” choice (e.g., because regular exercising is healthy).

Drawing on the theoretical assumptions of the ART (Brand & Ekkekakis, 2018), my dissertation aimed to investigate active and non-active individuals’ automatic affective reactions to exercise-related stimuli, including their impact on exercising. In this synopsis, I will first introduce the central premises of the ART (Chapter 4), primarily focusing on the ART’s automatic affective (type-1) process and its components—that is, automatic

associations with exercise and the resulting affective valuation of exercise. Previous research has already explored automatic associations with exercise (Chapter 4.1), which are most commonly measured with indirect tests, and their role in exercise decisions. In my first publication, this research was summarized and evaluated in a systematic review (Chapter 4.1.1). Research on the affective valuation of exercise (Chapter 4.2) is rare and represents a new area of inquiry. First empirical evidence for this concept was proposed in my second publication (Chapter 4.2.1), in which the affective valuations' somatic core was approached by analysis of heart rate variability (HRV). The link between automatic associations and affective valuation (Chapter 4.3), as well as the connection with exercise behavior as described by the type-1 process in the ART, was investigated in my third publication (Chapter 4.3.1). Through applying different tests, automatic associations with exercise (assessed via a reaction time-based indirect test) and the affective valuation (approached by HRV analysis) could be separated from one another. After the methodological approach and the core findings of the conducted studies are outlined, methodical and theoretical implications of my findings are presented (Chapter 5).

3 Exercise motivation: Current challenges and a new approach

Health behavior is essential for maintaining, regaining, and improving health, as well as preventing illness (Cockerham, 2014). A variety of behaviors have been identified as positively related to health, including eating a healthy diet, not smoking, and getting regular health screenings (Conner & Norman, 2017). Regular physical activity and exercise¹ are effective preventive and health-promoting strategies as well (Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017; Warburton, Nicol, & Bredin, 2006). However, although the majority of individuals know about the health benefits of exercising (Fredriksson et al., 2018), nearly one-third of the world's population (Guthold, Stevens, Riley, & Bull, 2018), including 57% of the population in Germany (Froböse, Biallas, & Wallmann-Sperlich, 2018), do not achieve the amount of exercise recommended by the World Health Organization (2010). My dissertation addresses one of the main themes in exercise psychology research: investigating and understanding the motivational processes behind exercise behavior and inactivity. This dissertation thereby contributes to the explanation of why some individuals struggle to exercise for the sake of their health.

Research from the last decade indicates that the strategies pursued to date to explain and change exercise participation are insufficiently effective (e.g., Ekkekakis & Zenko, 2016; Ekkekakis, Zenko, Ladwig, & Hartman, 2018; Rhodes & Dickau, 2012). It was criticized that the issue of exercise motivation has so far been investigated from a quite narrow theoretical perspective, with most strategies relying on social-cognitive theorizing (Ekkekakis & Zenko, 2016). The most common psychological theories of health behavior change that have been applied to exercise (e.g., the theory of planned behavior [Ajzen, 2011], social cognitive theory

¹ Physical activity and exercise are not interchangeable terms. Exercise is “a subcategory of physical activity that is planned, structured, repetitive, and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective” (World Health Organization, 2017). For the sake of clarity, the term *exercise* is used in the following discussion to refer to physical activity and exercise that is undertaken to positively influence one's health.

[Bandura, 1986], and the transtheoretical model [Prochaska, 2008]) share the core assumption that people base their decisions mainly on rational reasoning. However, it is indicated that human behavior is not solely driven by reflection (e.g., Simon, 1986; Kahneman, 2002). Therefore, the impact of automaticity and affect on exercising has been increasingly discussed in recent exercise psychology research. For instance, it has been shown that affect experienced during a bout of exercise (Ekkekakis & Dafermos, 2012; Rhodes & Kates, 2015) or affiliated with exercising (e.g., remembered or forecasted affect) is predictive for future exercise behavior (Ekkekakis, Zenko, & Werstein, 2018). One of the current challenges facing researchers in this field is understanding the mental processes that underlie the impact of affect experienced during, or associated with, exercise on exercise motivation and subsequent exercise-related decisions.

Dual-process models and theories (hereafter “dual-process theories”) offer a theoretical framework for explaining the interplay of automatic mental processes (e.g., the activation of evaluative associations with exercise) and reflective mental processes (e.g., concluding that exercising makes one feel better afterward). According to these dual-process theories, the automatic (type-1) process is fast and requires minimal cognitive resources and effort, whereas the reflective (type-2) process is slower and relies on controlled reasoning under the use of working memory (Evans & Stanovich, 2013). These theories have been intensively applied in social psychology and health psychology. Some prominent examples are the associative–propositional processes in evaluation model (Gawronski, Brannon, & Bodenhausen, 2017) and the reflective–impulsive model (Strack & Deutsch, 2004).

Within the last several years, dual-process theories have been developed that specifically account for exercise motivation (e.g., Conroy & Berry, 2017; Brand & Ekkekakis, 2018). The ART is especially relevant for this thesis. Unlike the other dual-process theories, the ART makes explicit presumptions about the hedonic motivational impact of an automatically-activated affective reaction (e.g., a negative “gut feeling” elicited when

thinking of exercise) on exercise-related decision making, which is integrated into the dual-process framework.

4 The affective–reflective theory of physical inactivity and exercise

The ART (Brand & Ekkekakis, 2018) focuses on the psychological processes in the precise moment that an exercise decision takes place, emphasizing the impact of a momentary affective reaction associated with exercise. This affective reaction is mainly colored by past affective exercise experiences. The ART proposes a dual-process framework involving two independent mental processes: a default, automatic, inherently affective process (type-1), and a reflective process characterized by propositional reasoning, cognitive effort, and control (type-2) (Fig. 1).

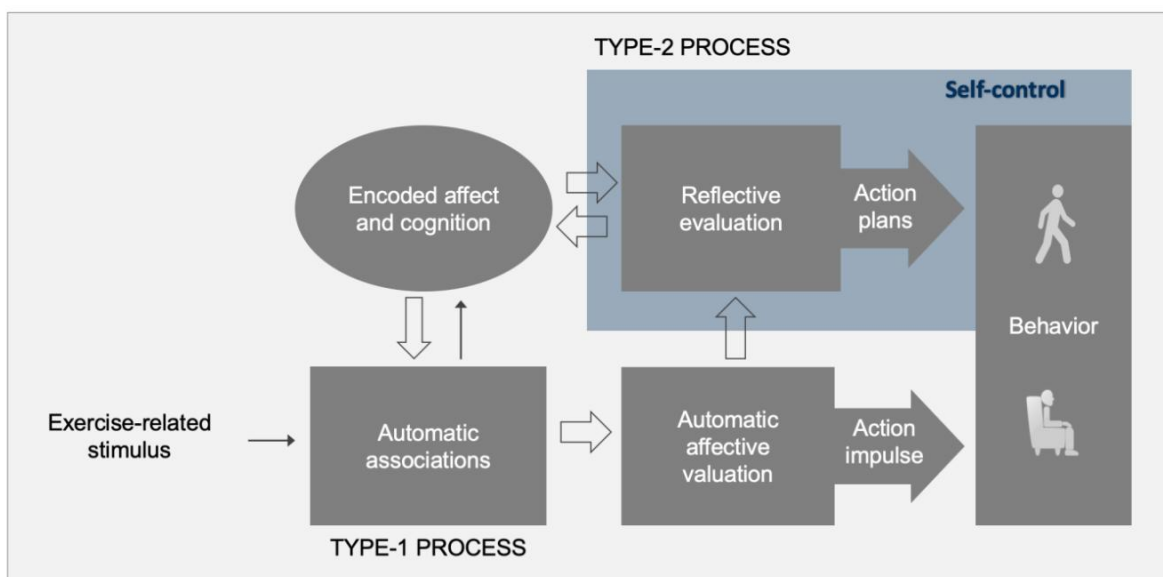


Figure 1. A graphical illustration of the affective–reflective theory of physical inactivity and exercise. Adapted from “Affective–Reflective Theory of physical inactivity and exercise. Foundations and preliminary evidence,” by R. Brand & P. Ekkekakis, 2018, *German Journal of Exercise and Sport Research*, 48(1), p.56.

According to the ART, external (such as advertisement of a fitness center) and internal (such as remembering one’s intention to go to the gym) exercise-related stimuli both elicit the

type-1 process. Automatically² activated associations with exercise, as well as associations linked to the present state (e.g., of inactivity), result in an automatic affective valuation (i.e., a positive or negative “gut feeling”) that directly influences exercise decisions with an action impulse, especially when self-control resources are depleted (Brand & Ekkekakis, 2018). A negatively valenced automatic valuation of exercise—an unpleasant “gut feeling”—may act as a restraining force that leads an individual to maintain their state of inactivity, whereas a positive affective valuation—a pleasant “gut feeling”—may drive the person to become active³. In addition, the affective valuation provides the basis for type-2 processing, which manifests in rational reasoning and reflective evaluations of exercise. Type-2 processing results in action plans (behavioral goals and intentions) that can represent a driving or restraining force for exercise activity in their own right. The automatic (type-1) and reflective (type-2) processes can interact with one another, as well: It is believed that the momentary availability of self-control resources influences whether the rational (type-2) action plans can override the automatic (type-1) action impulse (Brand & Ekkekakis, 2018; Hoffmann, Friese, & Wiers, 2008).

The focus of my dissertation is the type-1 process. The automatic affective reaction provides new insight into the mechanisms of exercise motivation that go beyond the traditional (social-cognitive) predictors. For instance, the ART offers an explanation for why individuals do not exercise even when they know that exercising is healthy—namely, the stronger restraining action impulse derived from a negative affective valuation of exercising (or a positive affective valuation associated with being seated [Brand & Ekkekakis, 2018]). Investigating an individual’s automatic affective reaction (i.e., the activation of automatic associations, the resulting automatic affective valuation, and the action impulse) associated

² The degree of automaticity of a mental process is defined by the extent to which it is: unintentional; outside of awareness; efficient (i.e., requiring few mental resources); and uncontrollable. Preconscious and postconscious automatic processes can be separated (Bargh, 1994).

³ This hypothesis is based on the idea of partial psychological hedonism (Murphy & Eaves, 2016) and Lewin’s field theory (Lewin, 1943).

with exercise reminders would, therefore, contribute to a better understanding of the motivational processes behind exercise decisions and behavior.

In the following section, the concepts of automatic associations and automatic affective valuation will be described, along with potential measurements that can be used to approach these constructs.

4.1 Automatic associations with exercise

Automatic associations with exercise rely on mental associations between the concept of “exercise” and other semantic concepts in memory. They are based on past exercise experiences (such as the feeling of shortness of breath during a run) or evaluations of exercise (e.g., exercise is healthy) that leave traces in memory. It is believed that any activation of a stimulus concept (e.g., “exercise”) automatically reactivates associated concepts (such as “displeasure,” “sweat,” “exertion”) (Brand & Ekkekakis, 2018).

There is already some research on automatic associations with exercise (sometimes also termed automatic or implicit evaluations of exercise or automatic affective attitudes), which have so far been studied using so-called “indirect tests.” Prominent examples of such indirect measurements include the implicit-association test (IAT) introduced by Greenwald, McGee, and Schwartz (1998), and the evaluative priming task developed by Fazio, Sanbonmatsu, Powell, and Kardes (1986). These indirect measurements infer mental contents, such as associations, evaluations, and attitudes, from participants’ performance on experimental paradigms—for example, reaction times or error rates in speeded categorization tasks (Gawronski, 2009). Underlying these indirect methods is the assumption that the to-be-measured mental content automatically influences the reactions of the participants in the task (Gawronski & Hahn, 2019). Although there is an ongoing debate about the additional impact of controlled processes on the outcome of indirect tests (e.g., Sherman, 2008), these tests remain popular in social and exercise psychology.

The goal of my first publication was to systematically summarize the current exercise psychology research on automatic associations with exercise measured via indirect tests and their role in determining exercise motivations and behaviors.

4.1.1 Publication 1: Automatic evaluations and exercising: Systematic review and implications for future research⁴

The objective of the first publication was to summarize, structure, and evaluate recent research on automatic associations with exercise⁵ in a systematic review. We set forth an overview of existing findings regarding the link between automatic associations and exercise-related constructs, such as exercise decisions or behavior (e.g., exercise amount and adherence), as well as the most common indirect methods used to measure automatic exercise associations. The study results and the use of the measurement methods were evaluated, and implications for future research were discussed. The following databases were screened for a systematic literature search carried out in May 2017: PsycINFO, PSYINDEX, PsycARTICLES, SPORTDiscus, and PubMed. The study selection process followed the PRISMA guidelines (Liberati et al., 2009). To be eligible for inclusion, studies were required to (1) report measuring automatic associations with an indirect measurement, and (2) assess some exercise variable. We identified 14 nonexperimental and six experimental studies that met these requirements (out of a total of $N = 1,331$ detected studies). After study quality was rated by two independent reviewers, the main study characteristics (participants, study design,

⁴ Schinkoeth, M. & Antoniewicz, F. (2017). Automatic evaluations and exercising: Systematic review and implications for future research. *Frontiers in Psychology, 8*:2103. doi:10.3389/fpsyg.2017.02103

⁵ Within the first publication (Schinkoeth & Antoniewicz, 2017), the term *automatic evaluation* was used to describe the output of automatic processing of an exercise-stimulus or event. Taking into account today's perspective (compare Brand & Gutmann, 2019) and the ART's presumptions, the identified studies relate to *automatic associations with exercise* (Brand & Ekkekakis, 2018). The applied indirect tests mostly study mental associations between "exercise" and evaluative concepts (e.g., "good" or "bad"). For this reason, the term *automatic associations with exercise* is used in this synopsis.

indirect measurement method, and main findings) were extracted, and the grade of evidence for each study was evaluated.

Results generally revealed small to large-sized effects (Cohen's *d*) for the link between automatic associations and exercise variables. Various relations between automatic associations and exercise-related variables—including visual attention, reflective evaluations of exercise, situated exercise decisions, and exercise behavior itself—were identified; for instance, individuals with positive automatic associations with exercise showed more exercise behavior, and higher exercise behavior was linked to more positive automatic associations. The small number of identified experimental studies points to the necessity for studies investigating cause–effect relations and conditions for the link between automatic associations and exercising.

We identified an immense heterogeneity regarding the applied indirect methods used to assess the automatic associations with exercise. The plurality of studies (40%) used the IAT (Greenwald et al., 1998) or its variants, such as the single-target IAT (Bluemke & Friese, 2008). However, specific properties (e.g., stimulus material) and applications varied across studies, even though using the same method. It became apparent that the plurality of studies did not reflect on the theoretical rationale for the use of a specific indirect measurement—that is, *how* and *when which* measurement should be used to answer a specific research question. Every measurement method comes with its particular advantages and disadvantages. Their fit with the respective research question must be carefully considered.

Taken together, automatic associations with exercise appeared to be relevant predictors for exercise behavior and other exercise-related variables, providing evidence for a central assumption of the ART's type-1 process (Brand & Ekkekakis, 2018). Furthermore, indirect methods seem to be appropriate to study automatic evaluative associations. The choice for a suitable measuring method should be based on thorough theoretical considerations.

4.2 Automatic affective valuation of exercise

Interpreting the research on automatic affective (type-1) processes summarized in the presented and other systematic reviews (e.g., Chevance, Bernard, Chamberland, & Rebar, 2019) from today's perspective, very few studies (e.g., Antoniewicz and Brand [2014] who used an affect misattribution procedure [AMP; Payne, Cheng, Govorun, & Stewart, 2005]) came closer to what is defined as *automatic affective valuation of exercise* in the ART. The affective valuation is the result of a (re)activation of mental associations (e.g., “exercise” and “fun”) and somato-affective bonds (e.g., the feeling of exertion) formed through one's past experiences with exercise⁶. Unlike automatic associations, the automatic valuation of exercise has an affective quality: It includes core affective feelings of pleasure or displeasure that arise directly from the body. This relates to the definition of core affect as a “neuro-physiological state consciously accessible as a simple, primitive, nonreflective feeling most evident in mood and emotion but always available to consciousness” (Russell & Feldman Barrett, 2009, p. 104). The core affective feeling can be dimensionally classified according to its affective valence (positive–negative) and level of connected arousal (activation). Moreover, core affect as a “neuro-physiological state” is accompanied by activity in the autonomic nervous system (ANS), as well as facial and vocal changes (Russell, 2003).

Brand and Gutmann (2019) conclude that exercise researchers should begin to investigate the somato-affective basis of the automatic valuation—in other words, how an affective valuation can be evoked—and its somatic core can be measured. The psychophysiological changes and behavioral reactions associated with the arousal and valence of core affect pave the way for measuring methods that approach these changes. A candidate indicator of the somato-affective core is heart rate variability (HRV), which has already been recognized as an indicator of regulated emotional responding (e.g., Appelhans & Luecken,

⁶ The (re)activation of both mental associations and somato-affective bonds represents an updated view on the occurrence of the affective valuation (see Chapter 5 for a more detailed discussion).

2006). My second publication examined and evaluated the applicability of HRV analysis to approach the somatic core of the affective valuation of exercise.

4.2.1 Publication 2: Listening to the heart. Getting closer to the somatic core of affective valuation of exercise through heart rate variability analysis⁷

ANS activation associated with a core affective feeling as part of an affective valuation can lead to changes in heart rate (HR; e.g., Russell, 2003) and HRV (Koval et al., 2013). HRV is defined as the variation in time intervals between successive heartbeats. Whereas HR can be taken as a combinatory indicator of regulatory processes in both the sympathetic and parasympathetic divisions of the ANS, evidence suggests that reactivity in (vagal) HRV represents parasympathetic activity when respiration rate and depth are sufficiently controlled (e.g., Laborde, Mosley, & Thayer, 2017). Lower vagal activity and a decrease in HRV have been shown to be connected to higher affective arousal (Choi et al., 2017) and negative affect (Ratanen, Laukka, Lethihalmes, & Seppänen, 2010). The relation between reactivity in HR and affect, however, remains inconclusive (Brouwer, van Wouwe, Mühl, van Erp, & Toet, 2013).

The ART assumes that viewing exercise-related pictures should lead to inter-individual automatic affective reactions (Brand & Ekkekakis, 2018). We hypothesized that a negative automatic affective valuation of exercise for less physically active participants would result in ANS activation and a decrease in HRV. Additionally, we anticipated that these participants would report a less positive reflective evaluation of the exercise-related pictures at the same time. Because of the more complex link between affect and HR, change in HR was explored without hypothesizing the direction of change. HR and HRV were recorded

⁷ Schinkoeth, M., Weymar, M., & Brand, R. (2019). Listening to the heart. Getting closer to the somatic core of affective valuation of exercise through heart rate variability analysis. *Psychology of Sport and Exercise*, 45:101541, doi:10.1016/j.psychsport.2019.101541

while participants viewed exercise-related and neutral control pictures in a laboratory setting. Results of a multiple linear regression ($N = 91$ participants; $M_{age} = 23.4 \pm 5.9$ years; 50 female) revealed that differences in exercise behavior triggered by exercise pictures could be regressed on reactivity in HRV, but not HR changes. Individuals who reported less exercise showed a decrease in HRV during the presentation of exercise-related pictures, and individuals who reported more exercise showed an HRV increase. As expected, those who were less physically active evaluated their feelings associated with the exercise pictures to be of lower affective valence and arousal. These evaluations of affective feelings were uncorrelated with the observed decrease in HRV.

In light of the ART, these findings were interpreted as evidence of an inter-individual affective reaction elicited at the thought of exercise and triggered by exercise-stimuli. It is therefore reasonable to assume that the peripheral psychophysiological activation reflected by HRV reactivity relies on processes associated with affective self-regulation of a core affect (Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). Based on the results, we concluded that HRV changes might represent a somatic correlate, probably indicating an automatic affective valuation of exercise.

4.3 The link between automatic associations and the automatic affective valuation of exercise

As described above, the ART makes certain assumptions regarding how automatic associations and the automatic affective valuation of exercise are linked and related to exercise behavior (Brand & Ekkekakis, 2018). The first publication (Schinkoeth & Antoniewicz, 2017) showed that automatic exercise associations, studied with indirect methods, are related to exercise. The second publication (Schinkoeth et al., 2019) demonstrated the applicability of HRV analysis for exploring a somatic component connected with an affective valuation of exercise. A third study was conducted to provide empirical

evidence for the interrelatedness of these two type-1 process components (i.e., automatic associations and affective valuation), as defined in the ART.

4.3.1 Publication 3: Automatic associations and affective valuation of exercise: Disentangling the type-1 process of the affective-reflective theory of physical inactivity and exercise⁸

This study used a multi-methodical strategy. HRV analysis was used to approach a somatic correlate of the affective valuation (Schinkoeth et al., 2019). In addition, based on the recent findings of Brand and Ulrich (2019), a facial expression (FE) task was conducted that attempted to measure the affective valence of the automatic valuation.

A single-measurement study with a within-subject experimental variation was conducted. In the first step, a recoding-free and single-target variant of the IAT (RF-STIAT; Brand & Utesch, 2019) was used to assess automatic evaluative associations with exercise. Participants then worked through the adapted FE task (Brand & Ulrich, 2019), in which they were asked to respond to both exercise-related and control stimuli with either a positive FE (smile) or a negative FE (frown). Participants should be faster in giving affective valence compatible responses (e.g., a smile after exercise pictures) than incompatible responses (e.g., a smile after neutral pictures). Those who had a positive automatic valuation of exercise were expected to smile after exercise-related pictures faster than after neutral pictures; likewise, those with a negative automatic valuation of exercise were expected to frown more quickly after exercise-related pictures. HRV reactivity to exercise pictures was measured as described in Schinkoeth et al. (2019). Reactivity in HRV and affective valence compatibility–incompatibility effects in the FE task were used as indicators of the affective valuation of

⁸ Schinkoeth, M. & Brand, R. (2019). Automatic associations and the affective valuation of exercise: disentangling the type-1 process defined in the affective–reflective theory of physical inactivity and exercise. Manuscript submitted for publication in *German Journal of Exercise and Sport Research*.

exercise-related stimuli. Finally, the number of exercise sessions per week was assessed using self-reports.

In accordance with the assumptions of the ART, it was hypothesized that more negative automatic associations with exercise would predict a more negative affective valuation. It was further expected that individuals with a more negative automatic response to exercise would report exercising less. Path analytical results using data from 69 adults ($M_{\text{age}} = 25.3 \pm 4.2$ years; 41 female) revealed that individuals with positive automatic associations with exercise showed a decrease in HRV while viewing exercise pictures. This decrease was able to predict a higher reported number of exercise sessions per week. Negative automatic exercise association led to an increase in HRV, and this HRV increase was associated with lower reported exercise sessions. The regression weights for the link between automatic associations and the affective valence compatibility–incompatibility effects in the FE task were in the expected direction (e.g., positive automatic associations were linked to faster smiles and slower frowns for exercise pictures) but remained statistically insignificant. Frown reaction time did not significantly predict exercise sessions. Unexpectedly, faster smiles on exercise-related pictures predicted fewer exercise sessions, and slower smiles predicted more exercise sessions.

We concluded that measuring automatic valuations' affective valence with the FE task did not work well in this study. The results for HRV reactivity were interpreted as evidence that automatic associations and a linked affective valuation of exercise, which is accompanied by somatic correlates, are already activated at the thought of exercise. Furthermore, this automatic affective response is connected to exercise behavior. These results thus confirm and expand upon the results of Schinkoeth and colleagues (2019) and provide empirical evidence for the type-1 process, as defined in the ART.

5 Conclusion

5.1 Summary

The consideration of hedonic determinants reflects an updated theoretical view on exercise motivation (Brand & Cheval, 2019; Rhodes et al., 2019). The main aim of this dissertation was to provide an insight into automatic affective reactions to reminders of exercise. In the process of doing so, I investigated the ART's theoretical assumptions regarding automatic associations with exercise and automatic affective valuations of exercise, as well as the link between both components of the automatic affective (type-1) process. To the best of my knowledge, this is the first and only time that these components of the ART's type-1 process have been investigated in this combined fashion.

My first publication offered a systematic review of (1) the relationship between automatic associations and exercise-related variables, and (2) indirect measurement methods previously used to assess automatic exercise associations (Schinkoeth & Antoniewicz, 2017). Automatic evaluative associations with exercise were found to be connected with various exercise-related phenomena, including exercise itself. Moreover, indirect methods (e.g., the IAT; Greenwald et al., 1998) seem to be suitable for assessing these automatic associations. Decisions for the use of specific indirect tests should, however, be based on a thoroughly considered theoretical justification.

The core affective feeling accompanied by the automatic valuation of exercise has thus far largely been neglected in research. Approaching the somatic core of the affective valuation with HRV analysis was the purpose of the second publication (Schinkoeth et al., 2019). As far as I know, this was the first use of a psychophysiological measurement to assess a somatic correlate of the affective valuation of exercise. The results imply that even the thought of exercise (while viewing exercise pictures) triggers an inter-individual affective reaction, and its somatic core is measurable, in this case, as reactivity in HRV.

The third publication was based on these findings. For the first time, we attempted to disentangle the components of the type-1 process (Brand & Ekkekakis, 2018). To achieve this objective, different measurements were applied. Automatic associations with exercise were measured with a variant of an IAT, the RF-STIAT (Brand & Utesch, 2019). HRV reactivity analysis was used to approach the somatic core of the affective valuation (Schinkoeth et al., 2019). The affective valuations' valence was assessed via an FE task (Brand & Ulrich, 2019), and exercise behavior was assessed via self-report. Results showed that automatic associations predicted physiological changes (i.e., HRV reactivity, which is likely a somatic correlate of the affective valuation). This somatic correlate of the affective valuation was able to explain self-reported exercise behavior, but results for the FE-task remained inconclusive.

In sum, my dissertation provides validity for a central assumption of the ART—namely, the existence of a detectable automatic affective response to exercise-related stimuli and its link to exercise behavior. A negative automatic affective reaction to the thought of exercise may act as a restraining force, which can be opposed to the rational reflection of doing more exercise in the future, and may lead the individual to remain inactive (Brand & Ekkekakis, 2018). To return to the central aim of this dissertation, the results of the conducted studies might facilitate a better understanding of such automatic affective processes and their role for exercise-related decisions. This dissertation thus advances the field of exercise psychology with regard to the influence of automaticity and affect on exercise motivation.

5.2 Implications

Several methodical and theoretical implications can be derived from the results of my dissertation. Selected implications are discussed below.

(i) Methodical implications

Previous research on the automatic affective (type-1) process has mainly investigated the mental associations with exercise. Further research on the affective component (i.e. affective valuation) of the type-1 process may allow further progress in the field. The study results imply that automatic association with exercise can be assessed separately from the automatic affective valuation of exercise. This separate assessment of automatic associations (e.g., via reaction time-based indirect tests) from the affective valuation of exercise (e.g., approached via HRV analysis) allow for a more thorough analysis of these two components of the automatic affective process. This might likely be relevant for researchers interested in investigating the occurrence and alteration of the components of the type-1 process⁹, as well as their interaction with the reflective process and impact on exercise-related decisions.

Using computerized indirect measurements can currently be considered as the standard procedure for studying automatic associations with exercise. To date, there is no such measurement method for assessing a momentary affective feeling, although a variety of methods have been proposed (e.g., Mauss & Robinson, 2009). In my second and third publication (Schinkoeth et al., 2019; Schinkoeth & Brand, *subm.*), psychophysiological measures were used to assess potential somatic correlates of the affective valuation. Using methods like these to assess psychophysiological (e.g., via measures of galvanic skin response) and neurobiological activation (e.g., via electroencephalography or functional magnetic resonance imaging [fMRI]) or expressive changes (e.g., in facial expressions)

⁹ For a discussion about interventions to change the automatic type-1 process, see, for instance, Frieze, Hofmann, and Wiers (2011).

associated with core affect may provide further insight into the automatic affective reactions to exercise-related stimuli. While the application of such measurements for the assessment of affect-related processes is already an established research method in biological psychology and affective science, such methods are very rarely used in the field of exercise psychology (cf. Jackson, Gao and Chen [2014], who used fMRI to assess affective reactions to exercise stimuli in obese Chinese women). The continuing widespread orientation towards social-cognitive paradigms in exercise psychology may have hindered progress in exercise-related research (Ekkekakis et al., 2018). Inputs from related research areas (e.g., the embodied cognition perspective in cognitive science) could provide new methodical and theoretical avenues for research on exercise motivation and the role of affective processes.

Using new methods and multi-methodical approaches, as in this dissertation, may also attenuate the impact of systematic measurement errors like common method bias¹⁰ (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003), a well-documented issue in research on exercise motivation and behavior (Ekkekakis, Zenko, Ladwig, & Hartman, 2018). Self-reports in questionnaires are particularly prone to such systematic measurement errors, which are caused, for instance, by social desirability or by using similar response formats for different variables of interest (Podsakoff et al., 2003). Still, self-reports represent the dominant measurement approach for research involving affective feelings, motivation, and behavior (Ortner & van de Vijver, 2015). This dissertation provides examples of the application of a variety of measurements and tests, including indirect reaction time-based methods, psychophysiological and biometric measures, and self-reports. This may encourage other exercise researchers to use measurement methods apart from self-reports.

¹⁰ This type of method bias is also termed common method variance. It refers to variance that is attributable to the measurement method rather than to the constructs the measures represent (Podsakoff et al., 2003).

(ii) Theoretical implications

Whereas some central theoretical assumptions of the ART are empirically supported by the results of the presented studies, this dissertation may also support refining or extending some of the ART's assumptions.

First, describing the ART's type-1 process as "inherently affective" (Brand & Ekkekakis, p. 54) can be misleading. Indicated by the presented study results and the theoretical assumptions of the ART, the type-1 process includes core affective feelings. This core affect is most likely part of the automatic valuation of exercise. Automatic associations are commonly defined as patterns of activation in a semantic network. This associative network is formed according to the principles of similarity and contiguity through learning (Strack & Deutsch, 2004). Consequently, the concept of automatic associations, in my view, represent the storage and processing of information. Automatic associations with exercise, hence, may not have an affective quality and should therefore not be affiliated with the label "affective." Using the terms *positive* or *negative* automatic associations may likewise lead to irritation. I suggest clarifying that, when referring to positive or negative automatic associations with exercise, it is inferred to the strength of the mental association between "exercise" and evaluative concepts like "good/pleasure" or "bad/displeasure." In sum, the term *affective* and related attributes should be used with caution in this context.

Second, the results of this dissertation may expand on the ART's conceptualization of the affective valuation. In the first outline of the ART in 2018, the authors defined *automatic affective valuation of exercise* as "tacitly assigning to a stimulus a positive (association with pleasure) or negative (association with displeasure) value" or "the tacit assignment of valence in an associative pairing, involved in type-1 processing" of an exercise-related stimulus (Brand & Ekkekakis, 2018, p. 54). In my view, this description of the affective valuation does not sufficiently reflect that "exercise is not only a social stimulus but also a physical or

somatic stimulus” (Brand & Ekkekakis, 2018, p. 54; see also Ekkekakis, 2005). The affective valuation of exercise likely emerges not only from activated mental associations with exercise but also from reactualized somato-affective bonds that are formed through an individual’s past somatic experiences with exercise. In another publication, Brand and Ekkekakis describe this process as activation of a “positive or negative, affective designation, along with a perhaps milder version of the associated physiological reaction (e.g., a knot in the stomach in the case of academic examination anxiety or a sense of physical exhaustion in the case of strenuous exercise)” (Ekkekakis & Brand, 2019, p. 135). This represents an advanced view of the origin and manifestation of the affective valuation of exercise. Describing the automatic affective valuation as a result of both mental associative processing and the reactivation of somatic bonds might make it more apparent that the affective valuation includes core affective feelings of pleasure or displeasure that arise directly from the body. The research conducted in my second and third publications can provide evidence for such a core affective feeling that is accompanied with the automatic valuation. However, it should again be emphasized that the somatic reaction, which was measured using HRV analysis (Schinkoeth et al., 2019; Schinkoeth & Brand, *subm.*), still only represents a somatic correlate of the affective valuation. With this attempt, hence, an affective valuation can only be approached. It may require other measurement procedures (e.g., the AMP [Payne et al., 2005] or fMRI) or a combination of different measurements to come closer to the affective core of the automatic valuation of exercise. Assessing the affective feeling by introspection could also be considered. The more or less pleasurable state included by the affective valuation may even reach awareness and thus may be assessable as a lived and embodied experience (Ekkekakis & Zenko, 2016). Further research is required to investigate whether and under which conditions this is the case in type-1 processing.

6 References

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7 Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources, and that I have explicitly marked all material which has been quoted.

place, date

signature

8 The publications as they were published or submitted

The three publications are listed below exactly as they were published or submitted.

They are attached in serial order.

1. Schinkoeth, M., & Antoniewicz, F. (2017). Automatic evaluations and exercising: systematic review and implications for future research. *Frontiers in Psychology*, 8:2103. doi:10.3389/fpsyg.2017.02103
2. Schinkoeth, M., Weymar, M. & Brand, R. (2019). Listening to the heart. Getting closer to the somatic core of affective valuation of exercise through heart rate variability analysis. *Psychology of Sport and Exercise*, 45:101541, doi:10.1016/j.psychsport.2019.101541
3. Schinkoeth, M. & Brand, R. (2019). Automatic associations and the affective valuation of exercise: disentangling the type-1 process defined in the affective–reflective theory of physical inactivity and exercise. Manuscript submitted for publication in *German Journal of Exercise and Sport Research*.

Automatic evaluations and exercising: Systematic review and implications for future research¹

Michaela Schinkoeth, Franziska Antoniewicz

Sport and Exercise Psychology, Department of Sport and Health Sciences, University of Potsdam, Potsdam, Germany

Correspondence:

Dr. Franziska Antoniewicz, Sport and Exercise Psychology, Department of Sport and Health Sciences, University of Potsdam, Am Neuen Palais 10, 14469 Potsdam, Germany.

antoniew@uni-potsdam.de

Keywords: automatic evaluation, exercise, associative, dual-process, implicit attitude, affective.

Abstract

The general purpose of this systematic review was to summarize, structure and evaluate the findings on automatic evaluations of exercising. Studies were eligible for inclusion if they reported measuring automatic evaluations of exercising with an implicit measure and assessed some kind of exercise variable. Fourteen nonexperimental and six experimental studies (out of a total $N = 1,928$) were identified and rated by two independent reviewers. The main study characteristics were extracted and the grade of evidence for each study evaluated. First, results revealed a large heterogeneity in the applied measures to assess automatic evaluations of exercising and the exercise variables. Generally, small to large-sized significant relations between automatic evaluations of exercising and exercise variables were identified in the vast majority of studies. The review offers a systematization of the various examined exercise variables and prompts to differentiate more carefully between actually observed exercise behavior (proximal exercise indicator) and associated physiological or psychological variables (distal exercise indicator). Second, a lack of transparent reported reflections on the differing theoretical basis leading to the use of specific implicit measures was observed. Implicit measures should be applied purposefully, taking into consideration the individual advantages or disadvantages of the measures. Third, 12 studies were rated as providing first-grade evidence (lowest grade of evidence), five represent second-grade and three were rated as third-grade evidence. There is a dramatic lack of experimental studies, which are essential for illustrating the cause-effect relation between automatic evaluations of exercising and exercise and investigating under which conditions automatic evaluations of exercising influence behavior. Conclusions about the necessity of exercise interventions targeted at the alteration of automatic evaluations of exercising should therefore not be drawn too hastily.

1 Introduction

Health behavior is not solely based on the reflective processing of information. It is also driven by automatic processes (Kahneman, 2003). This duality in the processing of information is theoretically described in dual-process theories (e.g. Evans & Stanovich, 2013;

¹ Schinkoeth, M., & Antoniewicz, F. (2017). Automatic evaluations and exercising: systematic review and implications for future research. *Frontiers in Psychology*, 8:2103. doi:10.3389/fpsyg.2017.02103

Gawronski & Bodenhausen, 2006; Strack & Deutsch, 2004) that distinguish between reflective (also termed ‘explicit, propositional’) and automatic (also termed ‘implicit, associative’) processing of information. Reflective processes are characterized by conscious deliberation on available information. Resulting reflective evaluations can be cognitively (e.g. ‘exercise is healthy’) or affectively (e.g. ‘exercise is fun’) shaped. *Automatic evaluations* as an output of automatic processes represent the affective, spontaneous and often unconscious reaction to a present stimulus or event. The reaction arises from the (often previously learned) mental associations between a target concept (e.g. exercise) and affective attributes (e.g. pleasant, tiring) and is based on the mental representation of one’s core affective reactions (Ekkekakis, 2013) to the stimulus or the event. According to dual-process theories, behavioral decisions are the result of interactions between both processes and thus between automatic and reflective evaluations (Gawronski & Bodenhausen, 2006; Strack & Deutsch, 2004). Automatic evaluations can be, but are not necessarily, in agreement with the reflective evaluations of a given object (e.g. Friese, Hofmann, & Wiers, 2011). One often referred to dual-process model, the associative-propositional model (APE), offers theoretical assumptions about mutual influences of automatic and reflective evaluations (Gawronski & Bodenhausen, 2011). For example, when automatic and reflective evaluations are inconsistent the initial reflective evaluation can be resolved in order to avoid aversive feelings. Furthermore, dual-process theories provide a framework for possible relations between automatic evaluations and exercise behavior. For example, according to the reflective-impulsive model (RIM, Strack & Deutsch, 2004) automatically activated associations trigger behavioral schemata that contain a motivational orientation toward approaching or avoiding the respective behavior. Automatic evaluations can thus for example help in understanding the paradoxical phenomenon of nonexercising. Individuals often know that exercising is good for them (reflective cognitive evaluation) but might automatically feel bad about it and thus decide against it (Bluemke, Brand, Schweizer, & Kahlert, 2010).

Theorizing on health behavior and health behavior change (e.g. Ajzen, 1985; Bandura, 1986; Deci & Ryan, 1980; Prochaska & DiClemente, 1984) focused for more than half a century on reflective processes and almost completely neglected the potential relevance of automatic antecedents of behavior. Major social-cognitive theories and the consequential health interventions assume that by providing information, intentions are changed, which will lead to respective changes in behavior. However, meta-analysis revealed only a weak relation between altered intentions and exercise behavior ($d = .15$; Rhodes & Dickau, 2012) and concluded that this relation has very low practical value. Others commented that moving away from the underlying social-cognitive ‘information processing paradigm’ (Ekkekakis, 2017), which is based on the meta-theoretical assumption that human beings act as rational information collectors who reflectively arrive at their decisions, could offer the opportunity to re-establish a new way of looking at a well-known phenomenon (i.e. why a large proportion of people fail to adapt to related health behavior interventions).

Since the effects of the mentioned interventions are rather sobering, Ekkekakis (2017, p. 86) anticipated that exercise psychology might be “undergoing a transition to dual-process theoretical models for conceptualizing the mechanisms that shape behavioral decisions about participation or nonparticipation in exercise and physical activity” and proposed that exercise psychology is already within a meta-theoretical crisis. Marteau, Hollands, and Fletcher (2012) offer a more applied perspective when acknowledging that health interventions that additionally target “automatic bases of behaviors may be more effective” (p. 1492) than interventions that address reflective processes solely. Following this line of argumentation Conroy and Berry (2017) consider automatic evaluations of exercise and physical activity as “potentially modifiable targets” (p. 236) for specific interventions.

Taking the described – possible – meta-theoretical transition into account, the first necessary step in order to better understand the potential of automatic process theorizing for exercise psychology is the systematic summary and evaluation of related, so far accumulated, empirical evidence.

A growing body of literature already underlines the relevance of automatic evaluations for health behaviors (Friese et al., 2011; Hagger, 2016) such as eating (Friese, Hofmann, & Wänke, 2008), smoking (Payne, McClernon, & Dobbins, 2007), alcohol intake (Houben & Wiers, 2008) and physical activity (Conroy, Hyde, Doerksen, & Ribeiro, 2010). There is ample evidence that automatic evaluations are related to exercise decisions and exercise behavior as well (e.g. Bluemke et al., 2010; Brand & Schweizer, 2015). Until now there has been no systematic review on automatic evaluations of exercising (AEE) and relations to exercise behavior. This lack of systematically gained, summarized and evaluated findings hinders progress in the field.

1.1 The focus of this review

This review focuses research on AEE and exercise. AEE can be related to physiological or psychological correlates of actual exercise behavior (e.g. exercise-related decisions) or exercise behavior itself (e.g. exercise amounts, exercise adherence). For the purpose of this review, we will use henceforth the umbrella term *exercise indicators* when referring to the various different measures of exercise-related constructs.

There are a variety of different terms when speaking about AEE. While some researchers seem to prefer the term ‘implicit attitudes’ (e.g. Calitri, Lowe, Eves, & Bennett, 2009; Markland, Hall, Duncan, & Simatovic, 2015), others have used the term ‘affective associations’ (e.g. Sala, Baldwin, & Williams, 2016). While the synonymous use of these terms is generally non-admissible, in this review, we checked thoroughly that all included studies targeted the affective core of the assessed evaluations in order to subsume the identified evaluations as AEE.

Literature on automatic evaluations describes various implicit measures for the assessment of automatic evaluations (for an overview see Gawronski & De Houwer, 2014). Prominent examples of these implicit measures are the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) and the Evaluative Priming Task (EP; Fazio, Sanbonmatsu, Powell, & Kardes, 1986). One common aspect of these methods is avoiding verbal or written self-reports (e.g. questionnaires) but rather employing computerized tools that indirectly assess AEE through within-person response time latencies, interpersonal reaction time differences and error rates. Resulting scores are interpreted as indices of the strength of associations between a target concept (‘exercise’) and affective attributes (valence). This review includes an overview of the most commonly used methods to measure AEE. Their expedient use is evaluated and implications for future research discussed.

The aim of this systematic review is to summarize and structure existing findings on AEE and relations to exercise indicators. In order to appraise the magnitude of the impact of AEE on exercise indicators, effect sizes will be extracted from the identified studies where possible.

2 Methods

2.1 Search strategy

A systematic literature search was carried out in May 2017 and conducted according to the PRISMA guidelines (Liberati et al., 2009). The following databases were used: PsycINFO,

PSYINDEX, PsycARTICLES, SPORTDiscus and PubMed (see footnote 1 for the used search terms). The search included the articles' titles, abstracts and keywords. We exclusively searched for peer-reviewed articles. There was no restriction on year of publication. Additionally, the reference lists of the identified articles were screened for further articles.

2.2 Eligibility criteria and study selection

The authors executed the initial screening of all retrieved studies on the basis of titles and abstracts independently from each other. The following inclusion and exclusion criteria were applied. Only original study reports in English or German were considered for integration in this review. Studies had to include an implicit assessment of AEE and some kind of exercise indicator to be eligible. Due to the use of diverse terms when referring to AEE we thoroughly checked if the assessed automatic evaluations in the identified studies fit to the described definition of automatic (also called 'spontaneous,' 'associative,' 'uncontrolled' or 'implicit') affective evaluations of exercising. Additionally, studies that did not examine exercise indicators were excluded. Exercise was defined as a "subset of physical activity that is planned, structured, and repetitive" (Caspersen, Powell, & Christenson, 1985, p. 126). Selected studies had to include human participants, be interventional or observational and gather cross-sectional or longitudinal data. Structured consultations between the two authors were carried out to eliminate disagreement regarding the eligibility of contentious studies. Afterwards, the two authors independently performed full-text reviews (based on the described inclusion and exclusion criteria) of all (pre-)selected articles. Finally, 19 records were included in further evaluation.

Referring to the proceeding of Rebar et al. (2016), all studies' grades of evidence based on study design were evaluated. Cross-sectional studies were considered to provide first-grade evidence, prospective and longitudinal studies were taken to represent the second grade of evidence and experimental studies were considered to provide third-grade evidence. Ratings could have been lowered when risks of bias were present. Risks of bias were classified on study level following the guidelines from the Qualitative Assessment Tool for Quantitative Studies (Effective Public Health Practice Project, 2009). More specifically, the following sources of bias were evaluated: selection bias (when individuals selected to take part in the study were not likely to be representative of the target population), inadequate blinding of study participants (e.g. high risk of bias when participants were aware of the research question), unreliable data collection methods (e.g. high risk of bias when data relied on self-reports only), existence of confounders (e.g. high risk of bias when important differences between groups were present prior to manipulations), and insufficient reports of withdrawals and dropouts (for further information see Effective Public Health Practice Project, 2009). Only one rating was lowered from second to first-grade of evidence (Craeynest, Combez, Deforche, Tanghe, & De Bourdeudhuij, 2008). Two cross-sectional studies showed risks of biases too (Berry, Spence, & Clark, 2011; Sala et al., 2016). Since both studies were already rated as providing first-grade of evidence the rating was not adjusted.

2.3 Data extraction and synthesis

We summarized the specific characteristics of the studies separately for nonexperimental (see Table 1) and experimental (see Table 2) studies. After coding each study, great heterogeneity in the applied implicit and outcome measures became apparent. Due to the incomparability of the studies it was decided that it was impossible to conduct a meta-analysis (Ioannidis, Patsopoulos, & Rothstein, 2008), so we carried out a systematic review instead. Nevertheless, we report significant effect sizes when available in the included studies. For reasons of clarity and comprehensibility we use Cohen's *d* as the effect size that expresses the degree of

difference between groups (or means). Originally reported effect sizes (e.g. η^2_{part} or η^2) were transformed into Cohen's d where necessary (Lenhard & Lenhard, 2016). To express the degree of association between variables, the correlation coefficient r or the unstandardized and standardized regression coefficients b and β were used. The determination coefficient R^2 indicates the proportion of variance in one variable that is explained by another variable.

3 Results

The literature search identified a total of 1,331 records (see Fig. 1 for PRISMA flow chart). No additional studies were identified through records' reference lists. After excluding duplicates and records not meeting the described eligibility criteria by checking the titles and abstracts, 31 records remained for full-text analysis of eligibility. In total, 19 records, including one that was a multi-study report of two separate studies, fulfilled the eligibility criteria and were included in this review. Of these, six studies had an experimental design and 14 were nonexperimental (cross-sectional or prospective).

3.1 Study Characteristics

3.1.1 Nonexperimental studies

From the included nonexperimental studies, 11 were cross-sectional and a further three had a prospective design, ranging from 3.5 months to 1 year and three to four times the measurement. The overall sample size of all included nonexperimental studies was $N = 1,157$ participants, ranging from 19 to 188 participants per study. Studies either explored male and female participants ($k = 13$) or focused on female participants only ($k = 1$). The samples included university students ($k = 7$) or groups of center exercisers or exercise course participants ($k = 2$), aircraftsmen ($k = 1$), cancer patients ($k = 1$), or obese children and adolescents ($k = 3$; which were compared to normal-weight children and adolescents). Average age ranged from $M = 12.79$ ($SD = 2.68$) to $M = 57.0$ ($SD = 11.01$). Due to their nonexperimental design, the majority of studies were rated as first-grade evidence ($k = 12$). Two studies reached a second grade of evidence rating (see Tables 1 and 2 for the rating of each study).

3.1.2 Experimental studies

All experimental studies investigated the effects of different interventions on the alteration of AEE ($k = 6$). One study additionally examined the effect of altered AEE on subsequent exercise behavior. The design of the interventions was experimental ($k = 4$) or quasi-experimental ($k = 2$), ranging from two to five experimental conditions. All studies applied a single-session intervention to alter AEE. Interventions were diverse, using Evaluative Conditioning (EC; see Hofmann, De Houwer, Perugini, Bayens, & Crombez, 2010 for an overview; $k = 2$), video clips depicting exercising individuals ($k = 1$) or an exercise advertisement ($k = 1$), a text with targeted exercise-related information ($k = 1$) or a guided imagery intervention ($k = 1$). The overall sample size was 771 participants, ranging from 41 to 213 participants per study. The participants comprised undergraduate psychology students ($k = 4$), undergraduate sport students ($k = 1$) or under- and postgraduate students of different subjects ($k = 1$). Average age ranged from $M = 19.06$ ($SD = 1.96$) to $M = 23.51$ ($SD = 4.36$). Studies included either male and female participants ($k = 5$) or investigated female participants only ($k = 1$). Three studies were rated as second-grade evidence and a further three studies were rated as third-grade evidence.

3.2 AEE Measurement

A first finding of this review concerns an immense diversity in the applied methods to measure AEE. Most of the identified studies used variants of the IAT ($k = 7$), which measure the strength of associations between semantic concepts stored in the memory. Standard IATs ($k = 4$; Berry et al., 2011; Chevance, Caudroit, Romain, & Boiché, 2016; Endrighi et al., 2016; Markland et al., 2015) are lexical sorting tasks in which stimuli from the target (e.g. 'exercise') vs. a comparison category (e.g. 'nonexercise') and from two evaluative categories (e.g. 'good' vs. 'bad') are mapped to the same computer key. The sorting task is easier for respondents when the concepts sharing the same response key are closely associated than when they are not. A person with negative AEE will respond more quickly when, for example, the words 'exercise' and 'bad' are mapped to the same key than when 'exercise' and 'good' are mapped to the same key. IAT scores are usually calculated using the difference between response times for related and unrelated word pairs (Greenwald, Nosek, & Banaji, 2003). Most IATs used pictures of exercise equipment or people engaging in exercise to represent the category 'exercise.' Therefore the depicted exercises differed in their intensity within and between the studies (e.g. running on a treadmill, stretching, performing resistance exercise, using an exercise ball; Markland et al., 2015). Astonishingly, all studies used different comparison categories (e.g. 'couch potato,' 'inactivity' or 'not exercise') represented by pictures of diverse activities (e.g. reading a book, resting, relaxing, watching television).

Two studies (Antoniewicz & Brand, 2016a; Brand & Antoniewicz, 2016) used the Single-Target IAT (ST-IAT; Bluemke & Friese, 2008), one study (Sala et al., 2016) used the Single-Category IAT (SC-IAT; Karpinski & Steinman, 2006) and another one (Antoniewicz & Brand, 2014) used the Brief IAT (BIAT; Sriram & Greenwald, 2009). In comparison to the original IAT, the ST-IAT, SC-IAT and BIAT emphasize the strength of associations between one focal target category (e.g. 'exercise') and its evaluation ('good' or 'bad') so that the participants only have to pay attention to one concept. In addition, the BIAT is an abbreviated version of the IAT and is thus timesaving. The two ST-IAT studies used the same eight pictures to represent 'exercise' (two different gymnastic exercises, strength training, running, swimming, volleyball, soccer and tennis). For the SC-IAT, words representing exercise in different intensities were used. For the BIAT, diverse exercise-related pictures represented the 'exercise' category. The BIAT study and one of the ST-IAT studies used symbols representing smiling or frowning faces (so-called 'emoticons') to depict the evaluative categories 'good' and 'bad.'

Three studies (Calitri et al., 2009; Craeynest, Crombez, De Houwer, & Deforche, 2005; Craeynest et al., 2008) applied the Extrinsic Affective Simon Task (EAST; De Houwer, 2003) to measure AEE. The EAST is conceptually related to the IAT but differs procedurally. In comparison to the IAT, participants respond to evaluative target words written in white and (exercise-specific) target words written in different colors (e.g. blue and green) by pressing one of two computer keys. Participants have to respond to white attribute words in terms of their valence whereas they have to ignore (the irrelevant) valence for colored words and respond only in terms of color. For example, participants are asked to respond with one key for 'good' and 'blue words' and with another for 'bad' and 'green words.' Participants with positive AEE perform more quickly when the target color of the (colored) exercise word and positive valence are sorted under the same response key. This effect relies on the congruence of the task-irrelevant valence of the target word and valence response. The intensity of exercises represented by the exercise words was diverse, ranging from walking to rowing and sprinting. Four studies (Antoniewicz & Brand, 2016a; Bluemke et al., 2010; Brand & Schweizer, 2015; Eves, Scott, Hoppé, & French, 2007) applied an EP task, which assesses automatic evaluative associations through a basic procedure of sequential priming (Fazio et al., 1986). In this task, a prime stimulus (e.g. exercise word or control word) is briefly presented and followed by a positive or negative word as target stimulus (e.g. 'pleasant,'

‘delightful’ vs. ‘repulsive,’ ‘disgusting’). Participants are asked to categorize positive target words to one key and negative target words to another. It is assumed that the presentation of the prime activates associated evaluative attributes. For people with positive AEE, the response to positive target words after an exercise prime is thus facilitated (in comparison to a control prime) and leads to faster response times. All these studies used exercise words representing various exercise intensities and, as the comparison or control category, words representing nonexercise activities, nonsense words or food words. Three studies (Antoniewicz & Brand, 2016; Bluemke et al., 2010; Brand & Schweizer, 2015) explicitly used exercise-specific positive and negative words (e.g. ‘relaxed’ vs. ‘exhausted’) as target stimuli.

Another five studies deployed implicit methods that do not rely on reaction time differences. The Go/No-go Association Task (GNAT; Nosek & Banaji, 2001) was applied in three studies (Berry, 2016; Berry, McLeod, Pankratow, & Walker, 2013; Berry & Shields, 2014). The GNAT is utilizable for the assessment of associations involving a single target category. Participants are asked to show a go response, by pressing a key, to target stimuli (e.g. exercise words and positive words) and a no-go response, by not pressing a key, to distracter stimuli (e.g. negative words). Unlike the IAT, differences in error rates (analyzed as sensitivity scores) of the responses to target words (e.g. ‘exercise’) indicate the strength of association between the target concept and a related evaluation. Positive AEE are assumed to ease the accuracy in discriminating ‘exercise’ and ‘good’ from distracters. All three GNAT studies assessed AEE with the target category ‘exercise’ and another ‘generic’ category. To represent ‘exercise,’ diverse words were used (e.g. ‘workout,’ ‘active,’ ‘sports’). Two studies (Antoniewicz & Brand, 2014; Karpen, Jia, & Rydell, 2012) made use of the Affect Misattribution Procedure (AMP; Payne, Cheng, Govorun, & Stewart, 2005). The AMP applies a sequential priming procedure to assess affective associations through evaluative responses (more pleasant or less pleasant). This method differs from the previously mentioned methods in several ways. The evaluated stimulus is an ambivalent Chinese character, which has to be classified as ‘more pleasant’ or ‘less pleasant’ than an average Chinese character. Prior to the Chinese character, exercise pictures or pictures from a ‘neutral’ category are presented as primes. The evoked affect is misattributed to the Chinese ideograph, which leads to shifts in the ‘more pleasant/less pleasant’ ratings. Primes were shown supraliminally ($k = 1$) or subliminally ($k = 1$). Karpen et al. (2012) used images of household items as ‘neutral’ primes whereas Antoniewicz & Brand (2014) used gray rectangles as control primes.

3.3 AEE and associated exercise indicators

The identified studies examined hypotheses on the relation between AEE and exercise indicators and checked for AEE differences between different groups (see Tables 1 and 2 for an overview). As for the applied methods, again, a respectable heterogeneity of the investigated exercise variables became apparent. The assessed exercise indicators can be categorized into three different domains. One group of studies addressed rather proximal exercise indicators, which directly represent quantitative (e.g. exercise volumes, exercise attendance) and qualitative (e.g. preferred exercise-setting) aspects of exercise behavior. A second group of studies targeted rather physiological or psychological variables that are associated with exercise behavior or decisions. These exercise indicators are summarized as distal exercise indicators (e.g. BMI changes, situated decisions to exercise or not to exercise). A third group of studies can be identified that assessed differences in AEE in specific target groups (e.g. obese individuals vs. normal-weight individuals).

3.3.1 Nonexperimental studies

3.3.1.1 Automatic evaluations of exercising and proximal exercise indicators

Within the nonexperimental studies targeting AEE and proximal exercise indicators, several studies focused on the differences between highly active and less active individuals. Bluemke et al. (2010) showed that ‘exercisers’ hold more positive AEE than ‘nonexercisers’ ($d = 0.59$). Likewise, Berry et al. (2011) found a marginally significant ($p < .06$) difference between AEE in highly active individuals (i.e. more positive AEE) and less active individuals ($d = 0.81$). Moreover, AEE were identified as predicting the self-reported frequency, the duration of typical exercise sessions and the amount of habitual exercise behavior per week. Calitri et al. (2009) revealed a significant, positive, small-sized correlation between AEE and self-reported exercise behavior in the past week ($r = .22$). The study of Scott, Hoppé, and French (2007) contributed to these findings as well and demonstrated that their participants’ AEE were associated with running behavior in the following week ($d = 0.63$), with those not running in the subsequent week having negative AEE.

Among the proximal exercise indicators that have been investigated are qualitative aspects such as the preferred exercise-setting. Fitness center exercisers had more positive AEE of fitness center exercising than a likewise physically active comparison group that exercised at other settings ($d = 0.59$; Antoniewicz & Brand, 2014). Antoniewicz and Brand (2016b) assessed adherence to a 14-week exercise course not only on the quantitative level (i.e. amount of overall participation) but also on the qualitative level (i.e. consideration of individual participation patterns such as returning to the course after a missed session). The three resulting adherence groups (i.e. maintainers, early and late dropouts) differed in their AEE ($d = 0.54$) already at the beginning of the exercise course and highlighted the predictive power of AEE for exercise adherence. Positive associations discriminated particularly well between later exercise course ‘maintainers,’ ‘early dropouts’ and ‘late dropouts’ at the beginning of the exercise course.

Not all studies found the expected associations between AEE and proximal exercise indicators. In a longitudinal prospective study with female, previously diagnosed cancer patients, baseline AEE did not predict daily minutes of exercise after two, four or six months. The authors argued that this lack of association might be due to generally positive AEE with limited variability in the study sample (Endrighi et al., 2016). Furthermore, AEE were not significantly associated with self-reported exercise behavior (Chevance et al., 2016) and self-reported frequency of moderate- and high-intensity activities in the past week (Eves et al., 2007).

3.3.1.2 Automatic evaluations of exercising and distal exercise indicators

Furthermore, distal exercise indicators and their association with AEE have been investigated. One of the first explorations of AEE showed that AEE influence people’s visual attention to exercise cues ($\beta = .29$). Extremely negative and positive AEE led to elevated visual attention to exercise words (‘U-shaped relation’; Calitri et al., 2009). Berry et al. (2011) targeted exercisers’ self-schema and illustrated that people who identify themselves as ‘exercisers’ had more positive AEE than ‘nonexerciser’ schematics ($d = 0.77$). Brand and Schweizer (2015) showed that AEE influence situated decisions to exercise ($\beta = .15$). The more positive the AEE, the more likely people were to decide in favor of exercise in the face of a behavioral alternative. Additionally, it was shown that the tendency to decide for or against exercise predicts the habitual amount of exercise per week.

Chevance et al. (2016) showed that AEE ($\beta = .25$) incrementally predicted exercise behavior in obese adults over and above Theory of Planned Behavior (Ajzen, 1985; $\beta = .38$) variables. These findings were not present in the general population. The Theory of Planned Behavior, as one typical representative of the social-cognitive 'information-processing paradigm' (Ekkekakis, 2017), involves reflective parameters like outcome expectancies and tries to explain intentions and resulting behavior from those variables. The authors concluded that AEE might be especially influential for obese individuals, which might be due to differences in self-regulation between obese and non-obese persons. Other studies explored correlations between AEE and reflective evaluations. Thereby some studies focused on reflective affective evaluations of exercise (e.g. 'How pleasant is exercising in a fitness center for you?,' Antoniewicz & Brand, 2014) whereas others measured the relationship between AEE and cognitive components of reflective evaluations (e.g. 'Exercising is: useless-useful, unnecessary-necessary, foolish-wise,' Karpen et al., 2012).

With regard to the association between AEE and reflective affective evaluations, Antoniewicz and Brand (2014) found no significant correlations in fitness center exercisers or the comparison group. Calitri et al. (2009) showed that neither reflective cognitive evaluations nor reflective affective evaluations interacted significantly with AEE in their association with self-reported exercise behavior in the past week. Moreover, AEE were not correlated with a combined measure of cognitive and affective components of reflective evaluations (Brand & Schweizer, 2015).

Some studies addressed discrepancies between AEE and reflective (affective and cognitive) evaluations of exercise. AEE and reflective evaluations alone did not significantly predict changes in self-perception and reflective evaluations after a self-perception manipulation. However, it was shown that self-beliefs ($\beta = .43$) and reflective evaluations of exercise ($\beta = .35$) were more strongly affected by a self-perception manipulation in individuals with larger discrepancies between AEE and reflective evaluations (Karpen et al., 2012). Brand and Antoniewicz (2016) advanced the idea of discrepant AEE and reflective affective evaluations. They developed combined scores for a more accurate description of the variable pairs' (AEE and reflective affective evaluation) sum and discrepancy. The sum of AEE and reflective affective evaluations predicted the actual exercise frequency of fitness club exercisers ($b = 3.83$, $R^2 = .10$), whereas the discrepancy between AEE and reflective affective evaluations predicted the self-reported aspired exercise frequency per week ($b = 4.74$, $R^2 = .10$) and the ratio of actual to aspired exercise frequency ($b = -0.10$, $R^2 = .12$). Large discrepancies were associated with high self-reported aspired exercise frequencies. The authors interpreted these inflated goals as being a result of mistrust in the negative AEE and thereupon asserted very positive reflective affective evaluations (i.e. 'idealized evaluations'; Brand & Antoniewicz, 2016). Low discrepancies predicted success in achieving the aspired exercise frequency. Also, AEE were positively associated with the ratio of actual to aspired exercise frequency ($r = .32$).

Not all expected associations between AEE and distal exercise indicators were found. For example, AEE neither predicted the affective response during moderate exercise nor the immediate post-exercise affective responses (Sala et al., 2016). Additionally, AEE were not associated with intention to run (Eves et al., 2007) or exercise self-efficacy (Endrighi et al., 2016).

Manifestations of AEE were also examined in specific target groups. Two studies focused on AEE and potential impact on obesity. They showed that obese youngsters neither had more negative AEE nor more positive automatic evaluations of sedentary behaviors than nonobese control individuals (Craeynest et al., 2005). A longitudinal study with obese children and

adolescents in an obesity treatment setting found that favorable AEE of high-intensity exercise were a predictor of positive BMI change after obesity treatment ($\beta = .51$; Craeynest et al., 2008). Additionally, a within-person change in AEE of moderate-intensity exercise was a predictor of BMI change after one year of treatment ($\beta = .89$). A decrease in self-reported bodyweight was associated with increasingly negative AEE. Due to the small sample size ($n = 19$) and contextual inferences (some participants completed the EAST during treatment sessions, other at home or at university) these rather unexpected results should be interpreted with caution.

3.3.1.3 Automatic evaluations of exercising in specific target groups

Included studies assessed their data in diverse samples (e.g. students, general population), which also differed in age and gender. Two previously mentioned studies explicitly investigated the effects of AEE in specific samples. Eves et al. (2007) examined the effects of AEE on brisk walking ($p > .05$) and running (i.e. intention to run, $p > .05$; running behavior, $d = 0.63$) together with other moderate exercises ($p > .05$) in military trainee aircraftsmen. Another study used female previously diagnosed cancer patients as participants. There were no significant effects of baseline AEE on exercise self-efficacy changes or exercise behavior after two, four and six months (Endrighi et al., 2016). Unlike the studies above (Craeynest et al., 2005, 2008) these studies did not compare specific samples to another sample (e.g. the general population). Due to the very specific populations the main study results should not be generalized.

3.3.2 Experimental studies

Experimental studies examined the possibility of altering AEE. Two studies used a computerized EC task (Antoniewicz & Brand, 2016a). In this task, pictures of exercising (conditioned stimuli) were repeatedly paired with positive or negative picture stimuli (unconditioned stimuli). The EC task resulted in differences in AEE between the group that should acquire positive AEE and the control group ($d = 0.77$) but not between the group intended to acquire negative AEE and the control group. Additional analyses revealed that changes in the group that acquired positive AEE were mainly driven by changes in associative connections between exercising and negative associations, in contrast to a facilitation of the associative connection between exercising and positive associations.

Markland et al. (2015) successfully altered AEE through a guided imagery intervention: AEE were more positive in the exercise imagery group ($d = 0.39$) than in a control group that imagined preparing a meal. Independently from the experimental manipulation, Markland et al. (2015) found that frequent exercisers had more positive AEE than less frequent exercisers ($d = 0.57$) and that AEE significantly correlated with reflective affective evaluations ($r = .32$) and reflective cognitive evaluations ($r = .24$).

In another study, participants read targeted exercise information that was incompatible with their pretest-AEE or pretest-reflective (affective and cognitive) evaluations of exercise. Results indicated that participants with positive AEE in the pretest who read information targeting negative reflective cognitive evaluations (e.g. information about negative health effects of exercise) unexpectedly showed even higher positive AEE in the posttest ($d = 0.71$; Berry, 2016).

Two other studies explored the alteration of AEE by using short video clips. One study used a short sequence from the TV show *The biggest Loser*, which depicted a strenuous exercise bout. There was neither a significant difference in AEE in comparison to a control group, nor a significant within-subject effect (Berry et al., 2013). In a study by Berry and Shields (2014),

participants watched a short health- or appearance-orientated exercise advertisement. There were neither group differences nor significant within-subject differences in AEE.

To date, only one study has investigated how altered AEE affect subsequent exercise behavior. Antoniewicz and Brand (2016a) showed that AEE altered by EC influenced the choice of exercise intensity on a bicycle ergometer (main effect: $d = 1.28$). The group that learned positive AEE selected significantly higher intensities than the control group ($d = 0.88$). There were no significant differences in selected intensities between the group that should acquire negative AEE and the control group.

4 Discussion

The main aim of this systematic review was to summarize and evaluate available research on AEE and exercising. Findings brought up small to large-sized correlations between AEE and exercise indicators in the vast majority of studies. Various implicit measures were used to assess AEE. Even when studies used the same measure, the specific application varied.

4.1 Implicit measures to assess AEE

To the best of our knowledge, so far five different implicit measures have been used to assess AEE in exercise-related studies. Although very different measures have been used and the temptation is high to hand out advice that one might be the ‘best’ implicit measure for assessing AEE, it is neither possible nor advisable to recommend “a particular paradigm as the best” (Gawronski & De Houwer, 2014, p. 293). In order to decide which measurement tool to use, every researcher has to answer the questions (among others) *what* exactly should be measured, as well as *how* and *when* it should be assessed. Since each measure has characteristic features, the fit between the respective research question as well as the underlying theoretical assumptions and the implicit measure’s specific procedure is decisive. For all of these questions, the identified studies can provide some, albeit no complete, answers.

In the identified studies the predominant implicit measure is the IAT and variants of it (used in 40% of exercise-related studies). This finding corresponds with the dissemination of implicit measures in social cognition research in general where standard IATs are used in nearly every second published study (Nosek, Hawkins, & Frazier, 2011). As described before, standard IATs require two opposing categories, i.e. the target category and one for comparison. The studies in this review deployed ‘couch potato,’ ‘inactivity’ and ‘not exercise’ in the classical IAT, which nicely illustrates the difficulty in finding a clear conceptual opposite of ‘exercise’ (Rebar, Ram, & Conroy, 2015). In order to maximize the conceptual overlap between the implicit measure and the research design (Gawronski & De Houwer, 2014), researchers interested in AEE should check carefully whether their research questions include a comparison of ‘exercising’ with another behavior. If not, other implicit measures might be more suitable for the respective research question. Only very few authors directly stated in their studies *why* a specific measurement procedure was used. Brand and Schweizer (2015) used an EP task and argued that the underlying mechanism (i.e. spontaneous evaluation of a stimulus) was closely related to the task requirements in their dependent variable (i.e. spontaneous decisions for or against exercising). The fit between research question and used method was thus explicitly taken into account. Antoniewicz and Brand (2014) targeted the automatic characteristic in AEE. They applied an AMP with subliminal stimulus presentation in order to conclude more easily on the automatic basis of AEE.

Exercising itself is a very complex and diverse behavior, which has to be reflected in AEE assessment. This systematic review has enumerated many different kinds of stimuli that have been used to assess AEE. Some of these stimuli represent the diversity more, some less. Again, the fit between the behavior of interest and the selected stimuli representing this behavior has to be considered. Some studies applied a very narrow focus and selected stimuli representing one specific behavior (e.g. fitness center exercising) in order to explain this tangible behavior (Antoniewicz & Brand, 2014), others used a broad range of stimuli in order to explain exercising behavior in general (e.g. Berry et al., 2011; Bluemke et al., 2010; Brand & Schweizer, 2015). A good indication of the selection of stimuli is the set provided by Rebar and colleagues (2016). They aimed to establish population-level evidence of the most common exercise stimuli and ranked the 20 most-named activities when asked to report words relevant to the term 'exercise.'

When measuring AEE and exercise indicators, it is essential to bear the affective nature of AEE in mind. This focus led to the exclusion of some studies that assessed automatic associations in the context of exercising but highlighted aspects other than the affective one (e.g. health; Berry, Rogers, Markland, & Hall, 2016, and exercise importance; Forrest, Smith, Fussner, Dodd, & Clerkin, 2016). This differentiation is especially important when correlating AEE with reflective evaluations that measure more (see Brand & Schweizer, 2015; Calitri et al., 2009) or fewer (see Karpen et al., 2012) affective components.

Moreover, decisions about *how* to measure AEE should be guided by careful theoretical deliberations on the basis of dual-process theories. For the included studies, surprisingly, only a limited amount of studies explicitly referred to a dual-process theory in the theory section. Even less studies described relevant theoretical assumptions made by the stated dual-process theory (e.g. Berry et al., 2011; Bluemke et al., 2010) or, beyond that, directly explained how the theoretical assumptions guided decisions on an appropriate method to measure AEE (e.g. Brand & Antoniewicz, 2016).

The question *how* to measure AEE even includes one more issue. When the appropriate measure and stimuli are selected, the gained AEE scores can be calculated (even within the same measure) in different ways. Social cognition research is growing and progressing fast, which, for example, has led to alternative scoring algorithms for IATs. The established IAT *D*-Score has been extended to the *DW*-Score (Chevance, Héraud, Guerrieri, Rebar, & Boiché, 2017) and the *IP*-Score (Rebar et al., 2015), which have already been tested in the context of physical activity.

Lastly, the question *when* to measure AEE has been handled very differently in the identified studies. Prospective or retrospective assessments and mean scores resulting from the assessment before and after exercising have been used. While none of these approaches is right or wrong per se, the implications from each study vary widely. The retrospective assessment after an exercise bout could thus differ from prospectively assessed ones, due to the triggered automatic associations of exercising. Sound theoretical deliberations should thus guide the decision on the measurement point, in order to prevent a blending of findings, which can a priori be expected to be very different.

The (in)stability of automatic evaluations (Gawronski, Morrisson, Phills, & Galdi, 2017), in the context of physical activity (Hyde, Elavsky, Doerksen, & Conroy, 2012) and exercise (Antoniewicz & Brand, 2016a), has been much debated. Gawronski et al. (2017) demonstrated that automatic evaluations are less stable (weighted average $r = .54$) than conceptually corresponding reflective affective evaluations (weighted average $r = .75$). This finding can have methodological reasons, but can also be theoretically expected. For example,

APE (Gawronski & Bodenhausen, 2011) points out that automatic evaluations are activated and altered on the mere basis of feature similarity and spatiotemporal contiguity whereas reflective evaluations are validated on the basis of logical consistency. Again, clarity on the underlying theoretical foundations of the study and on the measured construct can explain the assessment of sometimes more transitory or more long-lasting associations.

In sum, many different measures have been used to assess AEE. Quoting Nosek et al. (2011), the last few years of research can be characterized as the “Age of Measurement because of a proliferation of measurement methods and research evidence demonstrating their practical value for predicting human behavior” (p. 152). We claim to choose carefully between the available measures. They cannot be treated as substitutable and come with particular advantages and disadvantages that could fit or not fit with the research aim.

4.2 AEE and exercise indicators

The current research was able to detect multiple associations between AEE and exercise indicators. As a first result of this systematic review, the examined exercise indicators were classified as proximal or distal in order to better systematize and evaluate the findings. Whereas the applied proximal indicators are akin in some ways (e.g. assessment of exercise amounts), the distal exercise indicators we identified were very diverse, making it very difficult to relate the findings to each other.

4.2.1 Proximal exercise indicators

Quantitative aspects of exercising, such as the amount of exercise per week, have been examined repeatedly. In particular, the association between differently pronounced AEE in individuals with higher or lower exercise amounts has been confirmed in a number of studies. For the studies with similar exercise indicators, the seemingly comparable results need to be critically evaluated. In general, the literature underscores that frequent exercisers hold more positive AEE than less frequent exercisers and highlights the predictive power of these AEE. However, only a very limited number of studies used objective measures such as accelerometers to collect actual behavioral data. Since self-reports are susceptible to overreporting and recall bias (Duncan, Sydeman, Perri, Limacher, & Martin, 2001) and could be biased by specific self-concepts (especially when referring to exercising; Brewer, Raalte, & Lindner, 1993), the collected data might not represent the actually executed exercise behavior. Although this inadequacy represents a systematic error within each study that does not necessarily influence the targeted association with AEE, the external validity and the comparability with other studies are limited. Using a more objective measurement for exercise behavior should become the rule rather than the exception in order to improve the precision and accuracy in future AEE research.

Taking a closer look at the different exercise intervals that have been associated with AEE, huge differences become apparent. While Antoniewicz and Brand (2016a) successfully demonstrated immediate behavioral differences after altering AEE, some studies used a time frame of one week (e.g. Calitri et al., 2009) and others referred to three- (Antoniewicz & Brand, 2016b) or six-month periods (Endrighi et al., 2016). Even though not all of these studies detected the generally found significant relation between AEE and exercise behavior (Endrighi et al., 2016), AEE seem to be linked to both short- and long-term exercise behavior. These findings correspond with results from other research areas where automatic evaluations have successfully been used to alter immediate food choices (Hollands, Prestwich, & Marteau, 2011) or to explain weight gain over a year (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010). However, due to the limited number of longitudinal studies included in this review the question whether AEE are better suited to predicting short- or long-term behavior

can and should not be answered on the basis of current empirical evidence. Nevertheless, reflections on theoretical assumptions of dual-process theories can help to become an insight about the possible impact of AEE for long- and short-term exercise behavior. For example, in the APE model (Gawronski & Bodenhausen, 2011), AEE provide an evaluative basis (default-interventionist conception) for behavior. This could, on the one hand, explain the short-term approach and help to understand immediate decisions for or against exercising (Brand & Schweizer, 2015). On the other hand, the conception does not exclude the assumption that AEE can be associated with habitual or long-term behavior. Long-term behavior can be understood as repeated decisions to engage in exercise, which are, as this review has demonstrated, influenced by AEE. Repeated exercise experiences, such as exercising with a pleasurable feeling connected to it, can, according to learning theory, be understood as positive reinforcement that gradually changes or manifests AEE (Strack & Deutsch, 2004) and thus facilitates exercising.

A further point of discussion is the generally gained knowledge from most of the studies that assessed proximal exercise indicators. With the help of these studies we know *how* AEE differ between, for example, exercisers and nonexercisers. However, we do not know *why* AEE differ or under *which* conditions they are decisive for behavior execution. Another interesting question might be whether AEE vary or fluctuate among individuals whose exercise behavior is similar. Although the empirical findings do not yet provide answers to these questions, dual-process theories offer a wide range of explanations. Again, the APE model as an example (Gawronski & Bodenhausen, 2011) outlines specific operating principles and conditions for both processes. The operating conditions, for example, comprise issues such as intentionality, awareness, efficiency and controllability (the ‘four horsemen’ of automaticity; Bargh, 1994) and describe exemplarily *how* the formation and expression of AEE takes place.

Another dual-process theory, the recently presented Affective-Reflective Theory (ART) of physical inactivity and exercise (Brand & Ekkekakis, 2017), describes under *which* conditions AEE have more or less impact on exercise behavior. One strength of ART is the explicit reference to the phenomenon of exercising and the unique bodily sensations related to it, which result in more or less pleasurable or displeasurable states during exercise. In the light of this theory, AEE are linked with action impulses of approaching or avoiding the bodily sensations associated with the behavior. As an operating condition, Brand and Ekkekakis (2017) designate the availability of self-control resources. Limited self-control resources (for an overview on the concept of self-control see Baumeister, Bratslavsky, Muraven, & Tice, 1998) would thus lead to a greater impact of AEE on exercise behavior. Some empirical findings might hint at this connection and outline the difficulties of individuals in adhering to an exercise regimen on days when self-control is lowered (Englert & Rummel, 2016), which could increase the impact of AEE. Additionally, it can be assumed that individuals with negative AEE require higher amounts of self-control in order to reach the same exercise behavior (e.g. amount of exercise per week) as those individuals with more positive AEE. Whereas the exercise behavior is identical, the need to overcome negative AEE and corresponding behavioral schemata of avoiding is debilitating and may hinder to maintain the behavior over a longer period.

4.2.2 Distal exercise indicators

Distal exercise indicators comprise a great variety of variables (see Table 1 and 2). Among these, reflective affective evaluations and their interaction with AEE have been examined several times. Thereby studies either focused on correlations (e.g. Antoniewicz & Brand, 2014) or on the individual predictive power of AEE and reflective affective or cognitive evaluations (e.g. Karpen et al., 2012). Three studies did not find significant associations

between AEE and reflective affective and/or cognitive evaluations (Antoniewicz & Brand, 2014; Calitri et al., 2009; Brand & Schweizer, 2015) while two studies found small-to-medium-sized associations between AEE and reflective affective and/or cognitive evaluations (Berry et al., 2013; Markland et al., 2015). The ambiguous findings can be explained by theoretical deliberations. As already mentioned dual-process theories postulate an interplay between AEE and reflective affective evaluations. Those interactions are, according to RIM (Strack & Deutsch, 2004) influenced by cognitive capacity, motivation and the amount of attention. The APE posits that the interplay of automatic and reflective evaluations is mainly driven by the consistency or inconsistency of both evaluations (Gawronski & Bodenhausen, 2011). Further research is needed to evaluate the theoretical assumptions and examine *how* and under *which* conditions AEE and reflective evaluations interact.

Most of the studies assessed AEE and reflective affective evaluations distinctly. While this approach is necessary in order to get a better understanding of AEE and its unique impact on exercise behavior, it does not necessarily correspond to the theoretical assumptions of dual-process theories. According to dual-process theories, behavioral decisions are the result of interactions between both processes and thus between AEE and reflective affective evaluations (Gawronski & Bodenhausen, 2006; Strack & Deutsch, 2004). For example, according to APE, this interplay can either be described as a ‘bottom-up’ influence (see Gawronski & Bodenhausen, 2011), in which automatic evaluations influence reflective evaluations, or as a ‘top-down’ influence, which operates in the opposite way. One possible ‘bottom-up’ influence could occur in the case of inconsistency between evoked AEE and consciously validated reflective affective evaluations. In order to avoid aversive feelings due to the resulting cognitive dissonance (Festinger, 1957), reflective affective evaluations would be adjusted. These kinds of adjustments should be taken into account when designing a study. Brand and Antoniewicz (2016) directly referred to this default-interventionist rationale and conducted a computerized sequential assessment of AEE and reflective affective evaluations, yielding dependent values for the two constructs and thus taking into account this pair of evaluations’ temporal and functional relationship. ‘Top-down’ influences can be characterized by processes of affirmation or negation. Negating the reflective evaluation ‘I dislike exercising’ might strengthen the associative connection between ‘exercise’ and ‘dislike’ and translate into respective AEE.

In reference to ART (Brand & Ekkekakis, 2017), AEE and reflective affective evaluations can be understood to interact through reciprocal feedback. Those feedback loops are a prerequisite for learning and again highlight the default-interventionist connection between the two evaluations. Empirical examinations of the described mechanisms (such as by Berry, 2016) could help in understanding *why* AEE (and reflective affective evaluations) differ in some individuals and not in others.

In summary, the described state of evidence highlights the relevance of AEE for predicting proximal as well as distal exercise indicators. We want to emphasize that proximal and distal exercise indicators are very different things. Measuring people’s intentions or exercise-related self-efficacy can and should not be mixed up with exercising behavior itself. It has to be treated as a variable that can, but does not necessarily have to, lead to exercising.

4.3 AEE should not yet be targeted in exercise interventions

Some of the presented studies provide initial insights to the potential of targeting AEE in future exercise interventions (e.g. Antoniewicz & Brand, 2014; Calitri, 2009; Endrighi et al., 2016). However, before targeting AEE in exercise interventions, there has to be clarity on the causal connection between AEE and exercise behavior. Only six out of the 20 identified

studies employed an experimental design and only one study addressed the AEE-exercise behavior link (Antoniewicz & Brand, 2016a), which would suggest a causal relation between AEE and exercising.

The general accessibility of AEE for interventions was addressed in five studies. These studies used different approaches to test the alterability of AEE: Either a theoretically driven or a more application-oriented approach was used. The theoretically driven approach (Antoniewicz & Brand, 2016a) used an EC task that, based on reflections of the formation of AEE in the APE model (Gawronski & Bodenhausen, 2006), systematically paired pictures of exercising (or nonexercising) with pictures eliciting positive or negative sensations. The encouraging result for possible interventions was the significant shift in AEE in the group acquiring positive AEE. Changes towards more negative AEE were not detected. In contrast to this approach, other experiments used materials such as advertisements or sequences from TV shows that might change AEE. Although the overall results are not consistent (e.g. Berry et al., 2013), an alterability of AEE by some of these techniques seems to be confirmed. Even though all experimental studies applied single-session interventions, they vary widely concerning contextual, procedural and temporal aspects. Whereas the shortest manipulation included the presentation of 85 seconds long video clips (Berry & Shields, 2014), other manipulations took the participants several minutes to work on (Antoniewicz & Brand, 2016a, Berry et al., 2013). Longer manipulations, which might provide a bigger amount of associative learning possibilities, do not seem to be more successful (Berry et al., 2013) than rather short manipulations (Berry & Shields, 2014). Successful alterations of AEE could rather be due to the high density of the provided information (Antoniewicz & Brand, 2016a) or the personal involvement of the participants (Markland et al., 2015) in those studies. Replications of the described experiments may help to differentiate between effective and rather ineffective manipulations. It is important to note that there is no empirical evidence on the stability of the achieved changes. As the creation or modulation of associative links is based on the principle of contiguity, it is arguable how long-lasting the effects of these single-session interventions will be. Experimental designs that observe the sustainability of the manipulation effects or test the theoretical assumption that often co-activated mental representations lead to stronger AEE than singularly experienced contiguities, could serve as a basis for further deliberation about application in practice. More experimental evidence is urgently needed before we can ask for practical applications of the so far limited knowledge. The lack of research becomes particularly clear if one considers that only one experiment targeted the AEE-exercise behavior link. Antoniewicz and Brand (2016a) demonstrated that changes in AEE are connected to changes in actual exercise behavior. However, it is essential first of all to better understand what we are actually measuring with the implicit measures and what impact it has on the psychological system before considering whether, and how, we want to change that.

4.4 Unresolved issues

This review provides the first systematic overview on the relation between AEE and exercise. While some questions concerning the relation can be answered, it is important to note limitations that require further research.

First, it should not go unmentioned that the results may represent a publication bias due to the preferential publication of statistically significant results in the last few decades. It has been noted that the selective publication of significant results represents a great threat to validity for meta-analyses and systematic reviews since the “published literature is systematically unrepresentative of the population of completed studies” (Rothstein, Sutton, & Borenstein, 2006, p. 1).

Second, the diverging use of related terms concerning the examined psychological construct (e.g. implicit vs. automatic vs. associative or attitudes vs. evaluations) and the inadequate distinction concerning the observed behavioral phenomenon (e.g. physical activity vs. exercise vs. sport) might have hindered the identification of all studies targeting the relation between AEE and exercise. In order to collect all studies fitting to our aimed-at research question, a large variety of (partly synonymous terms) was used. In the future, the extent of the use of different terms when referring to the same psychological construct should be reconsidered in order to avoid misunderstandings.

Third, the number of studies that achieved a grade-three evidence rating is very low ($k = 3$; 15% of all identified studies). This was predominantly driven by the considerable amount of studies that applied correlational designs. Correlational studies qualify for many differentiated conclusions and are doubtlessly necessary when starting to explore a new research area. However, in order to examine and understand the cause-effect relation, experimental designs are required. In general, the research field would profit from more experimental studies that target the mechanisms explaining the link between AEE and exercising and allow a causal connection between the two to be inferred.

Fourth, we started this review with the statement that AEE might help to understand the paradox phenomenon of nonexercising (despite the individual's reflective evaluation that exercising is e.g. healthy). Whereas the review offers first insights on the relation between reflective evaluation and AEE (e.g. Antoniewicz & Brand, 2014; Calitri et al., 2009) and their respective impact on exercise decision and behavior (e.g. Brand & Schweizer, 2015), we want to point out that exercising and physical activity are two distinct behaviors that might be influenced by unique motivational factors (Biddle, 2011). Concluding from the provided findings on AEE and exercise behavior on the consequences for physical inactivity might be a shortsighted approach. None of the described studies directly assessed automatic evaluations of physical inactivity. We are aware of only one very recent study (Chevance et al., 2017) employing two different SC-IATs to assess both, AEE and automatic evaluations towards sedentary behavior in obese individuals. They revealed that only AEE were related to exercise behavior, whereas automatic evaluations towards sedentary behavior did not predict exercising. These findings underline the necessity to understand exercising and sedentary behavior as two distinct behaviors with different motivational antecedents.

5 Conclusion

As a result of our systematic review, we conclude that AEE are relevant determinants of exercise behavior, and are deserving much more research attention than they are actually given. Far-reaching conclusions are difficult to draw because of the immense heterogeneity concerning the observed exercise indicators, the implicit measures used to assess AEE and the underlying dual-process theories. This is tolerable, bearing the early phase of AAE research in sport and exercise psychology in mind. However, we claim that this review and the concomitant reassurance of the empirical evidence should mark the end point of this explorative phase of research. In order to achieve progress, a revision of the theoretical basis is urgently needed. We previously referred to Ekkekakis (2017), who diagnosed exercise psychology as being in a meta-theoretical crisis. In order to accelerate the transition from the 'information processing paradigm' to dual-process theoretical frameworks, dual-process theories have to be scrutinized more thoroughly. Hence, it is an immense deficit that only a limited number of studies sufficiently described the underlying theoretical deliberations. Moreover, short-sighted, selected imports of automatic variables into existing theories from the 'information processing paradigm' (for example, adopting the IAT for the add-on measurement of implicit attitude within the framework of the Theory of Planned Behavior)

might not go far enough and might thus not reflect the explanatory potential of dual-process theorizing. Before handpicking and integrating single parameters into established theories, more empirical evidence on the coherence and principles of the operation of automaticity is required. Consequently, as long as all these preconditions are not fulfilled, wide-ranging implications for exercise interventions should be postponed. Yet in sum, we fully agree that AEE constitute a worthwhile target for further basic research that might in the future, according to the findings, lead to practical implications.

6 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

7 Author Contributions

MS contributed to the conception and design of the review and performed the initial literature search. MS and FA independently rated the studies and extracted the key variables. MS extracted the effect-sizes and transformed them when necessary. All passages of the review have been written mutually by both authors.

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10 Footnotes

1. The following search terms were used to identify the relevant articles: i. Exercis* OR Sport* OR physical activit*, ii. AND implicit OR automatic OR unconscious OR non-conscious OR associative OR impulsive AND, iii. Attitude* OR Evaluation*/Process* OR Cognition*/Attitude* OR Evaluation* AND “Dual process theor*”/Attitude* OR Evaluation* AND “Dual process model*”/Attitude* OR Evaluation* AND Process* OR Cognition*.

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12 Tables and figure legends

12.1 Tables

Table 1.

Nonexperimental studies investigating automatic evaluations of exercising and exercise indicators (k = 14)

| Study | Participants | Study design | Main aim | AEE measure | Main proximal and distal exercise indicators | Main findings concerning AEE | Grade of evidence rating |
|------------------------------|--|-----------------|---|---|--|--|--------------------------|
| 1 Antoniewicz & Brand (2014) | 72 graduate sport and exercise students, $M = 26.00$ ($SD = 9.03$) | Cross-sectional | Examine the relation between AEE and preferred exercise setting | AMP with subliminal presented fitness center pictures | <i>Proximal:</i> preferred exercise setting (center exerciser, comparison group); reflective affective evaluations | A MANOVA indicated a significant group effect, and a test of between-subject differences revealed significant group effects on AEE ($d = 0.59$) and reflective affective evaluations ($d = 1.22$). AEE and reflective affective evaluations towards the fitness center setting were more positive for fitness center exercisers than in comparison group. Only nonsignificant correlations between AEE and reflective affective evaluations in center exercisers and comparison group. | First-grade |

- 2 Antoniewicz & Brand (2016b) 88 exercise course participants, $M = 24.98$ ($SD = 6.88$) Prospective, 14-week exercise program Examine the impact of AEE for exercise course adherence BIAT with exercise or nonexercise activities pictures and emoticons (good, bad) Proximal: objective assessment of exercise adherence (resulting in: maintainer, early dropouts, late dropouts) ANOVA showed that AEE were similar for the three exercise adherence groups at the beginning. A MANOVA revealed a significant group effect on positive and negative exercise associations ($d = 0.54$). Results of a post hoc discrimination analysis indicated that positive exercise associations contributed more to adherence group classification than negative associations. Second-grade
- 3 Berry, Spence, & Clark (2011) 53 undergraduate university students, $M = 21.9$ ($SD = 5.4$) Cross-sectional Examine differences in AEE in people with different exercise self-schemas (exercisers, nonexercisers) IAT with exercise pictures and evaluative words Proximal: activity level (four groups of exercisers) Distal: exercise self-schema (exerciser, nonexerciser) ANOVA and post hoc tests between exercise groups showed a marginally significant ($p < .06$) difference between AEE in the most active group (i.e. more positive AEE) and the groups with a lower exercise level ($d = 0.81$). ANOVA and post hoc tests revealed that AEE of 'exerciser schematics' were significantly more positive than in 'nonexerciser schematics' ($d = 0.77$). First-grade

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|---|--|--|-----------------|--|---|--|---|-------------|
| 4 | Bluemke, Brand, Schweitzer, & Kahlert (2010) | 94 university students, $M = 23$ ($SD = 3.3$) | Cross-sectional | Investigate the relation between AEE and habitual exercise volumes/short-range exercise behavior | EP with exercise-specific or generic verbs as prime stimuli and positive or negative exercise-specific or generic words as target stimuli | <u>Proximal</u> : exercise status: exercisers (non-sport students), exercisers (sport students), nonexercisers; habitual exercise behavior (frequency, duration and amount per week) | ANOVA indicated that both exerciser groups hold significantly more positive AEE than nonexercisers ($d = 0.59$). Ordinal regressions showed that AEE predicted self-reported frequencies of exercising, durations of typical exercise sessions and overall amounts of exercising per week. | First-grade |
| 5 | Brand & Antoniewicz (2016) | 44 fitness club exercisers, $M = 41.27$ ($SD = 14.06$) | Cross-sectional | Examine the impact of automatic-reflective affective evaluation discrepancies on exercise behavior | ST-IAT with exercise pictures and emoticons (good, bad) | <u>Proximal</u> : aspired exercise behavior; actual/behavior; actual/aspired exercise ratio | AEE was significantly correlated with the actual/aspired exercise frequency ratio ($r = .32$). Multiple regression analyses showed that ARED_sum predicted the actual exercise frequency, $b = 3.83$ ($R^2 = .10$). ARED_diff predicted the aspired exercise frequency, $b = 4.74$ ($R^2 = .10$) and the actual/aspired frequency ratio, $b = -0.10$ ($R^2 = .12$). | First-grade |
| | | | | | | <u>Distal</u> : reflective affective evaluations; automatic-reflective affective evaluation discrepancy (ARED) scores: sum (ARED_sum) and differences (ARED_diff) of | | |

| | | AEE and reflective affective evaluation scores | |
|---|---------------------------------------|---|--|
| 6 | Brand & Schweitzer (2015) | 74 university students; 36 women, $M = 23.2$ ($SD = 3.8$), 38 men, $M = 26.1$ ($SD = 3.6$) | Cross-sectional |
| | | Identify the impact of AEE, reflective (cognitive and affective) evaluations on situated decisions about exercising | EP with exercise-specific or generic words as prime stimuli and positive or negative exercise-specific words as target stimuli |
| | | | Path analyses revealed that AEE was not associated with the reflective evaluations. AEE significantly predicted situated decisions to exercise ($\beta = .15$) additionally to the reflective evaluations. The more positive the reflective evaluations and AEE, the more likely participants are to decide in favor of exercising in the face of a behavioral alternative. Together, AEE and reflective evaluations explained 61% of variance in the situational decisions on exercise variable, which in turn predicted duration of exercise per week. |
| 7 | Calitri, Lowe, Eves, & Bennett (2009) | 125 students, $M = 23$ ($SD = 6$) | Cross-sectional |
| | | Relation of attention bias, automatic and reflective affective and cognitive | EAST with exercise and neutral/contrast words |
| | | | <u>Proximal</u> : exercise amount <u>Distal</u> : situated decisions to exercise; reflective (cognitive and affective) evaluations |
| | | | Significant correlation between AEE and exercise behavior ($r = .22$). No reliable linear correlation between AEE and visual attention bias but results of curve estimation revealed a significant 'u-shaped' |

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|---|---|---|-----------------|---|-----|---|--|-------------|
| 8 | Chevance, Caudroit, Romain, & Boiché (2016) | 59 obese participants, $M = 34.7$ ($SD = 12.3$) and 94 participants from the general population, $M = 50.6$ | Cross-sectional | Investigate the additional contribution of AEE in the TPB framework | IAT | <u>Distal</u> : reflective affective evaluations; reflective cognitive evaluations; visual attention | quadratic relationship ($\beta = .29$). Additional moderated hierarchical regression analyses showed that AEE did not significantly moderate the association between attention and exercise behavior. Separate hierarchical multiple regression analysis revealed that reflective cognitive evaluations and reflective affective evaluations did not significantly interact with AEE in their association with previous exercise behavior. Sequential multiple regression showed that attention bias to exercise along with AEE are significantly associated with exercise behavior ($R^2 = .14$). | First-grade |
| 8 | Chevance, Caudroit, Romain, & Boiché (2016) | 59 obese participants, $M = 34.7$ ($SD = 12.3$) and 94 participants from the general population, $M = 50.6$ | Cross-sectional | Investigate the additional contribution of AEE in the TPB framework | IAT | <u>Proximal</u> : physical activity and exercise behavior in the past week <u>Distal</u> : TPB variables | AEE was nonsignificantly correlated with physical activity and exercise behavior in the overall sample. Multiple regressions revealed that AEE ($\beta = .25$) additionally to TPB variables ($\beta = .38$) was a significant predictor of exercise behavior among obese | First-grade |

(*SD* = 8.9)

people, but not in the general population.

| | | | | | | | |
|----|---|--|---|--|---|---|-------------|
| 9 | Craeynest, Crombez, De Houwer, & Deforche (2005) 38 obese children and adolescents, <i>M</i> = 13.69 (<i>SD</i> = 2.63) and 38 normal-weight children and adolescents, <i>M</i> = 13.53 (<i>SD</i> = 2.52) | Cross-sectional | Identify differences of AEE in obese and normal-weight children | EAST with physical activity and exercise words for sedentary behavior, and activities in moderate and high intensity | <u>Distal</u> : Extrinsic response valence to exercise words (positive, negative) | A 2 (group) x 3 (exercise intensity) x 2 (word valence) ANOVA found no significant effects. Youngsters with obesity did not have more positive automatic evaluations towards sedentary activities. Neither did they have more pronounced negative AEE. | First-grade |
| 10 | Craeynest, Crombez, Deforche, Tanghe, & De Bourdeaudhuij (2008) 19 obese children and adolescents, <i>M</i> = 12.79 (<i>SD</i> = 2.68) | Prospective; 1 year, T0: baseline during first 3 weeks of treatment, T1: + 6 months, | Examine the influence of AEE on obesity treatment results | EAST with physical activity and exercise words for sedentary behavior and activities in moderate and high intensity | <u>Distal</u> : extrinsic response valence to exercise (positive, negative); ABMI | A 3 (exercise intensity) x 2 (word valence) RM-ANOVA at baseline AEE showed no significant effects. A 3 (time) x 3 (exercise intensity) x 2 (word valence) RM-ANOVA only revealed a significant main effect of time, <i>F</i> (2, 17) = 10.22. This indicates that participants reacted faster on persecuting tests. A standard | First-grade |

T2:
follow-up
after 1
year

multiple regression analysis showed that a change of AEE towards high-intensity exercise was a significant predictor of ABMI change after treatment ($\beta = .51$), adjusted for age, sex and baseline ABMI. Another multiple regression analysis revealed that only the change in AEE towards moderate exercise was a significant predictor of follow-up ABMI ($\beta = .89$), adjusted for age, sex and baseline ABMI.

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| 11 | Endrighi et al. (2016) | 100 female patients previously diagnosed with endometrial cancer, $M = 57.0$ ($SD = 11.01$) | Prospective; 6 month, T0: baseline, T1: + 2 month, T2: + 4 month, T3: + 6 month | Examine the influence of AEE on exercise behavior in cancer survivors | IAT | <u>Proximal</u> : daily minutes of exercise <u>Distal</u> : reflective affective evaluations; exercise self-efficacy | Linear mixed models revealed that baseline AEE were not significantly associated with subsequent exercise self-efficacy changes after 2, 4 or 6 month. Baseline AEE were significantly predictive for self-efficacy changes when considering reflective affective evaluations and self-efficacy at baseline ($r = .17$). No significant associations emerged between baseline AEE and daily minutes of exercise after 2, 4 or 6 months. | Second-grade |
|----|------------------------|---|---|---|-----|---|---|--------------|

- 12 Eves, Scott, Hoppé, & French (2007)
- 188 Royal Air Force trainee aircraftsmen, $M = 20.0$ ($SD = 3.7$)
- Cross-sectional
- Examine the impact of AEE on walking and running behavior
- EP with moderate and high-intensity exercise words as prime stimuli, and negative and positive exercise-unspecific evaluative words as target stimuli
- Proximal: walking behavior (pedometer for 1 week); self-reported exercise behavior in the past week (frequency for moderate- and high-intensity activities as well as for walking and running); running in following week
- Distal: intention to run
- For moderate- and high-intensity activities in the past week (running and walking excluded) a between factor ANOVA showed a significant main effect for word valence (good vs. bad, $d = 0.49$). Response latencies for the positive words were shorter. No differences between groups (high vs. low frequency of moderate- and high-intensity activities). There was a main effect for participation in running in the past week ($d = 0.63$). It was additionally shown that there was an interaction between participation in running in the next week and word valence (good vs. bad, $d = 0.62$). Those who did not run in the next week showed shorter response latencies for negative words and longer latencies for positive words.
- First-grade

- 13 Karpen, Jia, & Rydell (2012) 134 Cross-sectional undergraduate students, $M = n.a.$ ($SD = n.a.$)
 Examine the impact of IED toward exercise on changes in self-perception and reflective evaluations, by a self-perception manipulation
 AMP with exercise equipment pictures or household items
Distal: reflective (affective and cognitive) evaluations; IED; self-perception of exercise importance
 Multiple regression analysis showed that neither AEE nor reflective evaluations alone significantly predicted the change of self-perception or the change of reflective evaluations after a self-perception manipulation. There were effects for IED: self-perception ($\beta = .43$) and reflective evaluations ($\beta = .35$) of those with greater IED were significantly more strongly affected by self-perception manipulation. First-grade
- 14 Sala, Baldwin, & Williams (2016) 69 Cross-sectional psychology students, $M = 20.4$ ($SD = 2.4$)
 Investigate whether anticipated affective factors (e.g. AEE) are related to affective responses during and after exercise
 SC-IAT with words representing exercise moderate intensity (during, post-exercise)
Distal: affective response to exercise in moderate intensity (during, post-exercise)
 Regression analysis revealed that AEE did not significantly predict affective response during exercise. Additionally, AEE did not significantly predict immediate post-exercise affective response. First-grade

Note. ABMI = adjusted BMI; AEE = automatic evaluations of exercising; AMP = Affect Misattribution Procedure; ARED = automatic-reflective evaluation discrepancy; BIAT = Brief IAT; EAST = Extrinsic Affective Simon Task; IAT = Implicit Association Test; IED = implicit-explicit attitudinal discrepancy; EP = Evaluative Priming Task; TPB = Theory of Planned Behavior; SC-IAT = Single-Category IAT; ST-IAT = Single-Target IAT.

Table 2.

Experimental studies investigating automatic evaluations of exercising and exercise indicators (k = 6)

| Study | Participants | Study design | Main aim | AEE measure | Main IV | Main DV | Overall findings concerning AEE | Grade of evidence rating |
|-------------------------------|--|---|---|---|--|---|---|--------------------------|
| 1 Antoniewicz & Brand (2016a) | 64 undergraduate sport students, $M = 23.02$ ($SD = 2.44$) | Experimental; <i>intervention</i> : EC, participants randomized to 1 of 3 groups: positive EC ($n = 19$), negative EC ($n = 20$) and control ($n = 25$) | Investigate the alterability of AEE | ST-IAT with exercise pictures and words related to feelings and bodily sensations | EC with exercise and nonexercise-related pictures (CS) and pictures of people displaying strong positive or negative feelings (US) | <i>Distal</i> : AEE | ANOVA showed a significant group effect on AEE ($d = 0.70$). Planned contrasts revealed significant differences between the positive EC group and control group ($d = 0.77$). | Third-grade |
| 2 Antoniewicz & Brand (2016a) | 41 female psychology students, $M = 23.51$ ($SD = 4.36$) | Quasi-experimental; <i>intervention</i> : EC, participants were assigned to 1 of 3 groups incongruent to their previously | Examine the effect of altered AEE on subsequent exercise behavior | EP with exercise-specific or nonexercise words as prime stimuli and positive and negative exercise-specific | EC with exercise and nonexercise-related pictures (CS) and pictures of people displaying strong positive or negative feelings (US) | <i>Proximal</i> : subsequent exercise behavior (chosen exercise intensity on bicycle ergometer) | ANOVA showed a significant group effect on choice of exercise intensity ($d = 1.28$). Planned contrasts revealed that the positive EC group selected significantly higher intensities | Second-grade |

($n = 36$),
 positive
 cognitive
 ($n = 16$),
 control ($n =$
 39)

| | | | | | | | | | |
|---|---|--|--|--|--|---|---|---|-----------------|
| 4 | Berry, McLeod, Pankratow, & Walker (2013) | 138 undergradua te psychology students, $M = 20.4$ ($SD = 5.42$) | Experimental; <i>intervention</i> : the sequence from The Biggest Loser (BL) or American Idol (AI), participants randomized to 1 of 2 groups: BL ($n = 63$), AI ($n = 64$) | Investigate the alterability of AEE | GNAT with exercise or generic words as target category and affective words as evaluative category | Video clip with depiction of strenuous exercise (sequence from The Biggest Loser) | <i>Distal</i> : AEE; reflective affective evaluations ; mood (POMS); thought- listing valence | RM ANCOVA showed no significant differences in AEE between groups. There was no significant within- subject effect. Neither mood nor activity level were significant covariates. Correlation between the thought-listing valence score and AEE was significant ($r =$.39). There was a significant correlation between AEE and reflective affective evaluations ($r =$.25). | Third- grade |
|---|---|--|--|--|--|---|---|---|-----------------|

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|---|------------------------|-----|---|-------------------------------------|---|---|--|---|-------------|
| 5 | Berry & Shields (2014) | 213 | Experimental; <i>intervention</i> : health- or appearance-orientated exercise advertisement, participants randomized to 1 of 2 groups: health condition ($n = 110$), appearance condition ($n = 103$) | Investigate the alterability of AEE | GNAT with exercise or generic words as target category and affective or cognitive evaluative words as evaluative category | Video clip of exercise advertisement (health- or appearance-orientated) | <i>Distal</i> : AEE; automatic cognitive evaluations | MANCOVA revealed no significant main effect for video clip group. RM MANOVA showed a significant multivariate within-subject effect for differences between d' scores for good and bad automatic cognitive evaluations and AEE ($d = 1.88$). There were significant within-subject differences for automatic cognitive evaluations ($d = 1.85$), but not for AEE. | Third-grade |
|---|------------------------|-----|---|-------------------------------------|---|---|--|---|-------------|

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|--|--|---|-------------------------------------|---|--|---|---|--------------|
| 6 Markland, Hall, Duncan, & Simatovic (2015) | 160 undergraduate and postgraduate students, $M = 23.03$ ($SD = 4.83$) | Experimental; <u>intervention</u> : imagery intervention exercise or control, participants randomized to 1 of 2 groups matched by gender and exercise status: | Investigate the alterability of AEE | IAT with exercise pictures and evaluative words | Guided imagery of a visit to a fitness facility or of preparing a meal (control) | <u>Proximal</u> : exercise status <u>Distal</u> : AEE; reflective affective evaluations ; reflective cognitive evaluations | There were significant correlations between AEE and reflective affective evaluations ($r = .32$), and AEE and reflective cognitive evaluations ($r = .24$). A two-factor ANOVA (imagery condition x exercise status) found a significant main effect for imagery condition ($d = 0.41$) and exercise status ($d = 0.59$). No significant interaction. AEE were more positive in exercise imagery group than control group ($d = 0.39$). Frequent exercisers had more positive AEE than less frequent exercisers ($d = 0.57$). | Second-grade |
|--|--|---|-------------------------------------|---|--|---|---|--------------|

Note. AEE = automatic evaluations of exercising; CS = conditioned stimulus; DV = dependent variable; EC = Evaluative Conditioning; EP = Evaluative Priming Task; GNAT = Go/No-go Association Task; IAT = Implicit Association Test; IV = independent variable; POMS = Profile of Mood States; ST-IAT = Single-Target-IAT; US = unconditioned stimulus.

12.2 Figures

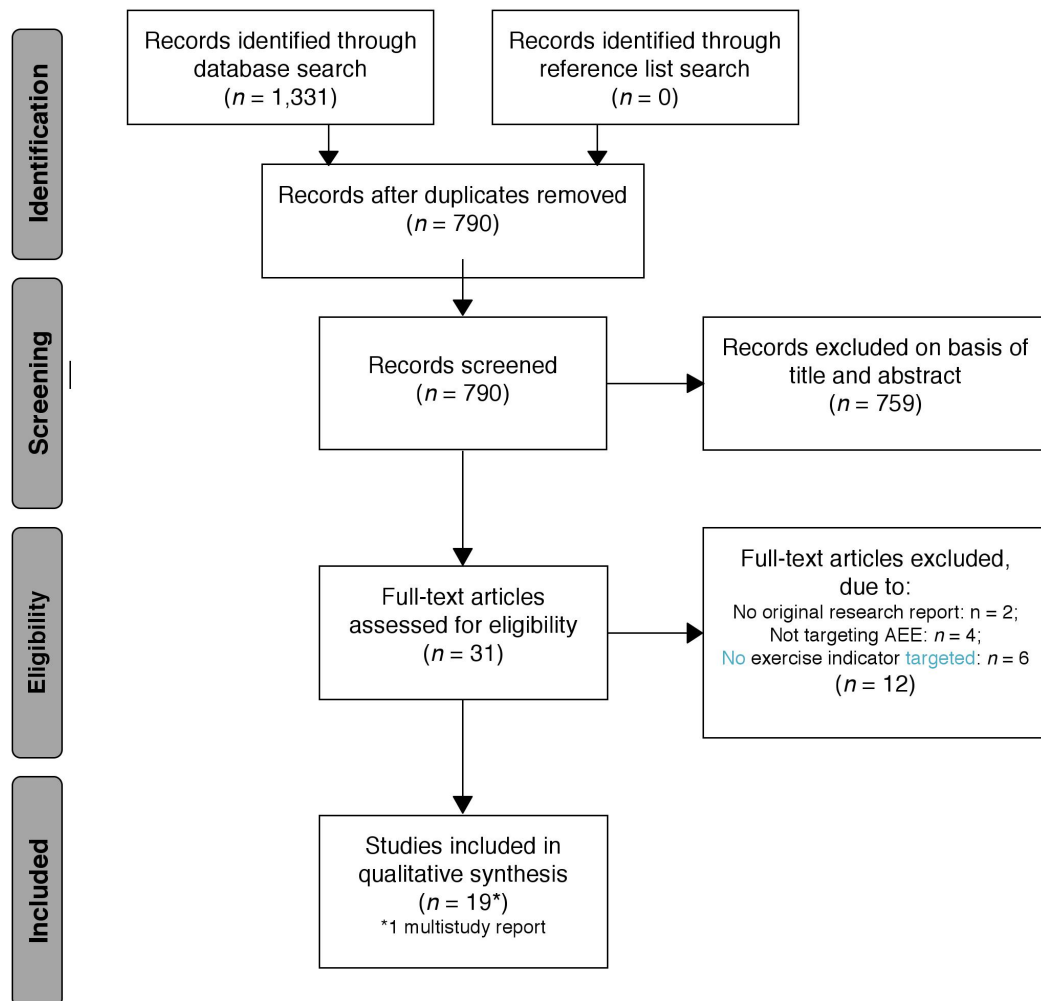


Figure 1. Study selection flow chart according to PRISMA statement (Moher, Liberati, Tetzlaff, & Altman, 2009).

Listening to the Heart.**Getting Closer to the Somato-Affective Core of Affective Valuations of Exercise through Heart Rate Variability Analysis¹****Abstract**

Objective. The affective-reflective theory of physical inactivity and exercise suggests that the mere thought of exercise can lead to an immediate somato-affective response which, if negative, will drive a physically inactive person to maintain his or her current exercise avoidant behavior. This study aimed to test the assumption that the somatic core of this affective response can be identified by means of heart rate variability (HRV) analysis. **Design.** This study followed a within-subject experimental design. **Method.** Participants were 91 adult men and women whose HR and HRV were monitored whilst they viewed exercise-related and control pictures in a controlled laboratory setting. **Results.** Analyses revealed a decrease in HRV during viewing of exercise-related pictures for less physically active participants. Less active participants reported that the same pictures elicited feelings with relatively low affective valence and arousal. There were no changes in HR. **Conclusion.** The findings indicate that core affective valuations are reflected in the body's psychophysiological reactions already at the mere thought of exercise.

Keywords: dual-process, motivation, valence, arousal, psychophysiology, self-assessment manikin (SAM)

¹ Schinkoeth, M., Weymar, M. & Brand, R. (2019). Listening to the heart. Getting closer to the somatic core of affective valuation of exercise through heart rate variability analysis. *Psychology of Sport and Exercise*, 45:101541, doi:10.1016/j.psychsport.2019.101541

Introduction

Why do people not exercise, despite knowing that exercising is healthy? Perhaps because the very thought of exercise makes them feel uncomfortable (Bluemke, Brand, Schweizer & Kahlert, 2010) and restrains them from altering their physically inactive lifestyle (Brand & Ekkekakis, 2018). The study described in this brief report focuses on inter-individually different somato-affective reactions to exercise cues and their correlations with exercise behavior.

The affective-reflective theory (ART) of physical inactivity and exercise (Brand & Ekkekakis, 2018) is a dual-process model derived from what is known about exercisers' and non-exercisers' affective responses to exercise. It assumes that exercise-related stimuli (spontaneous thoughts or environmental reminders, e.g. jogging shoes) trigger automatic mental associations (e.g. between jogging and aversion), resulting in an automatic affective valuation of exercise. Affective valuation is defined as the implicit assignment of a positive or negative value to a stimulus based on its association with pleasure or displeasure (e.g. a bad 'gut feeling' associated with the thought of exercising; type-1 process). Affective valuations are the basis for reflective evaluation (type-2 process) and can strongly influence subsequent reasoning, or directly create an action impulse (especially when self-regulation resources are low or depleted).

Central to the concept of affective valuation is the definition of core affect as a "neuro-physiological state, consciously accessible as a simple, primitive, nonreflective feeling" (Russell & Barrett, 2009, p. 104). Core affective feelings are experienced as integrated blends that have both a valence (pleasure - displeasure) and an arousal (activation) dimension, and are associated with activity patterns in the autonomic nervous system (ANS), e.g. changes in heart rate (HR; e.g. Russell, 2003) and heart rate variability (HRV; Koval et al., 2013).

HR can be taken as a combinatory indicator for regulatory processes in both the sympathetic and the parasympathetic division of the ANS. Higher HR often occurs when

sympathetic activity is higher than parasympathetic activity, but co-inhibition or co-activation of the two divisions can occur as well (Berntson, 2019). The relationship between affect and changes in HR is not yet fully understood and studies have shown inconclusive results (Brouwer, van Wouwe, Mühl, van Erp & Toet, 2013). Regulatory processes reflected in HR change, however, can be interpreted as adaptive responses to stress in its most general sense.

HRV is defined as the variation in the time intervals between successive heartbeats. Evidence suggests that HRV is a measure of parasympathetic (vagal) activity when respiration rate and depth are sufficiently controlled. It might be of particular interest for research on affect (Laborde, Mosley, & Thayer, 2017). Low HRV, which reflects reduced parasympathetic cardiac control, is assumed to indicate difficulty in regulating emotions and stress (Appelhans & Luecken, 2006; Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). For example, viewing unpleasant pictorial stimuli leads to lower levels of vagal activity than viewing neutral or pleasant pictures (e.g. Ratanen, Laukka, Lethihalmes, & Seppänen, 2010), and lower phasic HRV has been correlated with higher affective arousal (Choi et al., 2017). These findings can be interpreted in the light of the neurovisceral integration model (Thayer & Lane, 2000), according to which HRV can be used as an index for the regulation of affect via prefrontal-subcortical structures (Thayer et al., 2012).

The study described in this brief report attempted to get closer to the theoretically postulated somatic core of affective valuation and evaluation of exercise (Brand & Ekkekakis, 2018). On the basis of evidence that negative past experiences of exercise contribute to exercise avoidance and negative affective evaluations of exercise (e.g. Ladwig, Vazou & Ekkekakis, 2018), we wanted to show that exercise behavior can be statistically regressed on HR and HRV reactivity to exercise cues. We hypothesized that viewing exercise-related pictures would reduce HRV in physically less active participants, and that these participants would report less positive reflective evaluation of these exercise stimuli at the same time. Furthermore, possible reactivity in HR was explored (because of the probably more complex

interaction between the experience of affect and HR, without hypothesizing whether HR will slow down or accelerate).

Method

Participants

We collected data from 124 individuals. Participants were recruited from a university campus with students of different majors (e.g. sport and exercise, math, literature), without particular selection criteria. Data from 33 participants could not be included in our main analyses because of different reasons. Due to technical malfunctions we failed to obtain valid cardiac data from 14 participants. Difficulties with data storage caused the loss of another 14 cardiac raw data sets after HRV calculation. Due to incomplete questionnaire data we were unable to calculate exercise volume for a further 2 participants, and fitting the linear model to the data for our main analysis (see below) led to the exclusion of 3 more participants (multivariate outliers). The study sample for statistical analysis therefore consisted of 91 young adults ($M_{age} = 23.4 \pm 5.9$ years; 50 female).

Materials and Measures

Pictorial stimuli. Thirty exercise images without obvious affective content (e.g. facial emotion) were selected according to recommendations for adequate portrayal of the concept of exercise (Rebar et al., 2016). Images displayed exercise activities of different intensities. Another 30 images, classified as affectively neutral in the International Affective Picture System (Lang, Bradley & Cuthbert, 1997), were chosen as control stimuli.

HR and HRV. Heartbeat and intervals between consecutive heartbeats (inter-beat intervals) were measured with Polar RS800 and RS800CX heart rate monitors and chest belt sensors. Data preprocessing and score calculation was performed with Kubios HRV software (v3.0.0). HR is heart beats per minute. The root mean square of successive differences between normal heartbeats (RMSSD) was chosen as the HRV indicator. RMSSD is a time-domain index of HRV reflecting vagal tone (Thayer & Lane, 2000) and it is a valid measure

for HRV in ultra-short-term recordings, e.g. periods of between 10 and 60 seconds (Shaffer & Ginsberg, 2017). HRV scores were natural log transformed to account for skewed distributions prior to all further analysis (Laborde et al., 2017).

Reflective evaluation of exercise pictures. Ratings of affective valence and arousal for all picture stimuli (nine-point scales) were obtained using self-assessment manikins (SAMs; Bradley & Lang, 1994), i.e. a nonverbal pictorial assessment technique. In our study the item measuring valence (*SAM valence*) showed manikins ranging from smiling and happy to frowning and unhappy. The item measuring arousal (*SAM arousal*) showed manikins ranging from relaxed and sleepy to excited and wide-eyed. Participants indicated their answers by ticking a box over or between any two figures on both scales.

Habitual exercise volume. Weekly exercise volume was assessed with an adapted item from the International Physical Activity Questionnaire (IPAQ; Hagströmer, Oja, & Sjöström, 2006). We asked participants how much time they usually spend doing moderate or vigorous exercise (“... such as running, gym fitness, or playing tennis”). Participants reported how many times they exercised each week and the average duration of sessions, from which we calculated *exercise volume* (sessions per week × min per session).

Procedure

Tests were conducted under controlled conditions in the laboratory. First the participants were informed about all goals and the exact course of the study, and that they could cancel their participation at any time without any disadvantages for them. After the participants had signed full informed consent, the chest belt sensor was attached, and the participants were asked to sit in front of a black computer screen in a relaxed and quiet position for five minutes. The heartbeats recorded during this period were later used to calculate *HR rest* and *HRV rest*. Then the 60 pictures were presented for four seconds each in four blocks (separated by 10-second blank screens) of 60 seconds each. The first 15 neutral pictures (randomly selected and in random sequence), were followed by two blocks with 15

exercise pictures each (random block assignment and sequence), followed by the remaining 15 neutral pictures (random sequence). We informed participants that the exercise-related pictures were chosen to elicit their personal thoughts and feelings about exercise. The heartbeats recorded during the middle 30 seconds of the two neutral blocks as well as the two exercise blocks were later combined into one block each, leading to the four variables *HR neutral*, *HRV neutral*, *HR exercise* and *HRV exercise*. After watching the pictures the participants' heartbeat recordings were stopped and the participants rated the valence and arousal of all the stimuli using the SAMs (picture by picture, random sequence).

Formal Design, Tests Scores and Statistical Tests

This study followed a within-subject experimental design to investigate HR and HRV reactivity under the two experimental conditions 'exercise' and 'neutral'. Importantly, studies on the neurovisceral integration model had often investigated changes in resting (tonic) HRV (Laborde et al., 2017). However, we believe that comparisons with the neutral condition provide a more adequate baseline here, because already the attentional processes involved in the viewing of neutral pictures are not likely to remain without impact on HR and HRV measures (Quintana & Heathers, 2014). To investigate change from the neutral to the exercise condition, and taking into account the numerical values of inter-individually different mean scores which may be affected by confounding personal variables (e.g. correlations with fitness level), we calculated *HRV ratio* by dividing *HRV exercise* by *HRV neutral*, and *HR ratio* by dividing *HR exercise* by *HR neutral*. Negative scores indicate lower scores during the viewing of exercise pictures.

Statistical analysis implied descriptive statistics (means and standard deviations) for all variables, bivariate Pearson correlations between seven main study variables (*HR rest*; *HRV rest*; *HR change*; *HRV change*; *SAM valence*; *SAM arousal*; *exercise volume*), and two (for HR and HRV) dependent samples *t*-tests to check potential differences between the resting and the neutral condition. To test our main hypotheses multiple linear regression was

used to analyze whether reported *exercise volume* could be regressed on reactivity in *HRV change*, *HR change*, and the participants' subsequent reflective evaluation of the exercise pictures.

Results

Analyses revealed the foreseeable high negative correlation between HR rest and HRV rest (Table 1; *HR neutral*: $M = 74.1$, $SD = 10.9$; *HRV neutral*: $M = 3.7$, $SD = 0.5$). HR ($t[90] = 3.38$, $p < .01$, $d = 0.35$) was affected, HRV ($t[90] = -0.45$, $p = .65$, $d = -0.05$) was not affected by viewing neutral images (compared to the resting baseline values). The direction of HR and HRV correlations with exercise volume were as expected (more exercise should lead to greater fitness, thus lower HR rest and higher HRV rest), the 95% confidence intervals (*CIs*) included zero however (Table 1). All correlations between self-reported affective arousal and valence on one side, and HR and HRV change on the other side were small and possibly zero, according to the 95% *CIs* (Table 1).

Linear modeling revealed that *HR change*, *HRV change*, *SAM valence* and *SAM arousal* jointly explained 23.0% of variance in *exercise volume*, adjusted $R^2 = .23$, $F(4, 86) = 7.72$, 95% *CI* [.09, .38]. Assumptions for fitting this model to the data were met. Variance inflation factors indicated no problems with multicollinearity ($VIF = 1.23$ for *HR change*; $VIF = 1.21$ for *HRV change*; $VIF = 1.24$ for *SAM valence*; $VIF = 1.27$ for *SAM arousal*). The regression weights for *HRV change*, *SAM valence* and *SAM arousal* were statistically significant with $\beta = .27$ (95% *CI* [.06, .47]), $\beta = .23$ (95% *CI* [.02, .43]) and $\beta = .32$ (95% *CI* [.12, .53]) respectively, indicating that low exercise volume could be regressed on a reduction in HRV during presentation of exercise-related stimuli and association of the concept of

exercise with relatively low ratings of positive affect and affective arousal.² In contrast, the regression weight of *HR change* was not significant, $\beta = .11$ (95% *CI* [-.09, .32]).

Discussion

This study showed that differences in exercise behavior are indeed associated and can be statistically regressed on HRV reactivity to exercise cues. Those who reported less exercise had a lower HRV while viewing exercise-related pictures than those who reported more exercise. At the same time, and as expected, those who do less exercise evaluated feelings triggered by these pictures as of relatively low affective valence and arousal. These affective appraisals were uncorrelated with the observed decrease in HRV.

We suggest interpreting the HRV-related findings as evidence for inter-individual differences in psychophysiological affective responses to reminders of exercise. The observed dissociations between the psychophysiological measure and reports of affect are in line with previous research (e.g. Choi et al., 2017). Together these findings indicate that the two components of affective evaluation, the somatic core of automatic affective valuation and reflective affective appraisals, should be measured with separate tests.

Previous works suggested that low levels of physical activity and reduced fitness are associated with greater sensitivity to stress (Forcier et al., 2006). This may be reflected in generally higher HRV reactivity in less active people. With our design, we cannot completely rule out a bias of this effect, but we believe it is unlikely that this effect was determinant for our results, because there was an experimentally induced HRV change in frequent exercisers as well (i.e. higher HRV during exercise-related than during neutral stimuli, as indicated by HRV change ratios greater than 0; table 1). One possible explanation for this is that frequent

² These effects (significant regression weights) were replicated with the larger sample of $n = 103$ participants for whom only HRV scores but no HR raw data were available (see the corresponding information in the Participants section above).

exercisers felt familiar with the scenarios depicted in the exercise-related stimuli, and that no particular or positive feelings were triggered. Increased HRV could be interpreted as successful adaptive affective regulation (Thayer et al., 2012) or as a reflection of the association between wellbeing and exercise in frequent exercisers (see van Reekum et al., 2007 for a similar argument with respect to trait HRV).

Another point is that frequent exercisers may be better than infrequent exercisers to imagine themselves practicing the exercise behaviors presented in the pictures, and that our results could also be due to such a mental imagery effect. But our findings show that exercise-cues triggered a reaction different from the reaction to neutral pictures even in people who rarely engage in exercise. We interpret this difference as based on different affective regulatory processes, because reflective evaluations differed according to the different exercise levels.

In this study, we attempted to capture the somato-affective core of affective valuations of exercise by measuring changes in HRV. Affective valuations are an immediate, automatic affective response to an object or event (ART; Brand & Ekkekakis, 2018). We exposed participants to exercise-related pictures and asked to use them as personal reminders for exercise. Whilst we can assume that the onset of affective self-regulation processes - as indicated by stimulus-induced changes in HRV - were unintentional and automatic, the data presented here do not allow us to disentangle the automatic (affective valuation) and reflective components (affective evaluation) of this psychophysiological response.

From a psychophysiological perspective (i.e. the neurovisceral integration model; Thayer & Lane, 2000) the presentation of exercise-related stimuli to less physically active people can be interpreted as a potential stressor, which has the effect of reducing tonic prefrontal control of brain regions associated with affect (e.g. the amygdala). Disinhibition of prefrontal control permits an increase in the sympathetic influence on the heart (accompanied by less flexible parasympathetic control) leading to an increase in HR and lower vagally

mediated HRV (Thayer et al., 2012). Changes in HRV, such as those observed here, could thus be interpreted as a result of changes in cortical and subcortical activity caused by affective valuations and evaluations of exercise, which vary between individuals. All the more so as HR reactivity to exercise cues was uncorrelated with exercise behavior, we conclude that especially changes in parasympathetic activity (indexed by the observed changes in HRV) are linked to the somatic core of affect. At the same time, we emphasize that HRV remains to be an *indirect* measure of the somato-affective core in inter-individually different automatic valuations of exercise.

The limitations of the research presented here include the following. First, our analyses relied on self-reports of habitual exercise volume, which may have been overestimates. A more objective and prospective assessment of exercise behavior would be preferable in future studies. Second, future research should control for the effects of potential HRV confounders (e.g. smoking, body mass index; Laborde et al., 2017). And finally, third, we are suggesting to include stimuli representing physical inactive then as well, because theoretically such behaviors could also be associated with specific somato-affective reactions as well (Brand & Ekkekakis, 2018; Cheval et al., 2018). Further studies are certainly needed.

Conclusion

This study was derived from ideas connected with the ART of physical inactivity and exercise (Brand & Ekkekakis, 2018) and the aim was to examine the somato-affective core of individuals' affective valuations of exercise. We conclude that this somato-affective core can be captured using HRV analysis. Future studies should elaborate on the notion that the study of exercise-related affective processes should also consider the related somatic processes (compare also the somatic marker hypothesis; Damasio, 1996), with the aim of learning more about the potential role of physical sensations in the motivation to exercise.

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Table

Table 1

Means, standard deviations and correlations with confidence interval for main study variables ($N = 91$)

| Variable | <i>M</i> | <i>SD</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------------|----------|-----------|---|---------------------|------------------------|---------------------|------------------------|----------------------|---------------------|
| 1 exercise volume | 250.1 | 184.7 | - | -.14 [-.34, .07] | .16 [-.04, .36] | -.05 [-.25, .16] | .21* [.01, .40] | .41** [.22, .57] | .35** [.16, .52] |
| 2 HR rest | 75.9 | 12.3 | | - | -.69** [-.79, -.56] | -.05 [-.26, .16] | -.01 [-.22, .20] | .01 [-.19, .22] | -.10 [-.30, .11] |
| 3 HRV rest | 3.7 | 0.6 | | | - | -.04 [-.24, .17] | -.30** [.11, .48] | -.06 [-.26, .15] | .05 [-.16, .25] |
| 4 HR change | 1.0 | 0.04 | | | | - | -.41** [-.57, -.23] | -.15 [-.34, -.23] | -.02 [-.23, .19] |
| 5 HRV change | 0.02 | 0.2 | | | | | - | .02 [-.19, .22] | -.06 [-.26, .15] |
| 6 SAM arousal | 3.8 | 1.8 | | | | | | - | .44** [.26, .59] |
| 7 SAM valence | 6.5 | 1.0 | | | | | | | - |

Note. *M* and *SD* represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Automatic associations and the affective valuation of exercise: Disentangling the type-1 process of the affective–reflective theory of physical inactivity and exercise¹

Abstract

The decision to exercise is not only bound to rational considerations but also automatic affective processes. The affective–reflective theory of physical inactivity and exercise (ART) proposes a theoretical framework for explaining how the automatic affective process (type-1 process) will influence exercise behavior, i.e., through the automatic activation of exercise-related associations and a subsequent affective valuation of exercise. This study aimed to empirically test this assumption of the ART with data from 69 study participants. A single-measurement study, including within-subject experimental variation, was conducted. Automatic associations with exercise were first measured with a single-target implicit association test. Then the somato-affective core of the participants' automatic valuation of exercise-related pictures was assessed via heart rate variability (HRV) analysis, and the affective valence of the valuation was tested with a facial expression (FE; smile and frown) task. Exercise behavior was assessed via self-report. Multiple regression (path) analysis revealed that automatic associations predicted HRV reactivity ($\beta = -0.24, p = .044$); the signs of the correlation between automatic associations and the smile FE score was in the expected direction but remained nonsignificant ($\beta = -0.21, p = .078$). HRV reactivity predicted self-reported exercise behavior ($\beta = -0.28, p = .013$) (the same pattern of results was achieved for the frown FE score). The HRV-related results illustrate the potential role of automatic negative affective reactions to the thought of exercise as a restraining force in exercise motivation. For better empirical distinction between the two ART type-1 process components, automatic associations and the affective valuation should perhaps be measured separately in the future. The results support the notion that automatic and affective processes should be regarded as essential aspects of the motivation to exercise.

Keywords: heart rate variability, facial expression, somatic, dual-process, motivation

1. Introduction

Regular physical activity and exercise are effective health-preventive (Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017) and health-promoting strategies (Warburton, Nicol, & Bredin,

¹ Schinkoeth, M. & Brand, R. (2019). Automatic associations and the affective valuation of exercise: disentangling the type-1 process defined in the affective–reflective theory of physical inactivity and exercise. Manuscript submitted for publication in *German Journal of Exercise and Sport Research*.

2006). However, the analysis of global trends in physical activity indicates that worldwide more than 27% of adults are insufficiently active, according to the recommendations of the WHO (2010). In high-income countries, the level of inactivity is even higher (> 35%) and continues to rise (Guthold, Stevens, Riley, & Bull, 2018). Most health interventions today aim to change activity behavior by stimulating rational deliberation, e.g., about the health benefits of exercise. The approach underlying these interventions refers to the assumption that human decision-making is fundamentally rational (e.g., Brand & Cheval, 2019; Ekkekakis, Zenko, Ladwig, & Hartman, 2018). However, exactly this premise has never been without controversy (e.g., Simon, 1986). Hence, within exercise psychology, in the past few years, the investigation of the role of automatic and affective processes in health behavior change and maintenance has become a flourishing field (e.g., Ekkekakis & Brand, 2019; Rebar et al., 2016). Related to this novel line of research, a couple of new theories and models have emerged (e.g., Cheval et al., 2018; Conroy & Berry, 2017), of which the affective–reflective theory (ART) of physical inactivity and exercise (Brand & Ekkekakis, 2018) is under study here.

The ART is a dual-process theory with an explicit exercise psychological account that provides a theoretical framework for the interplay of automatic affective processing (type-1: fast and automatic in the sense that it requires minimal cognitive resources and effort; Evans & Stanovich, 2013) and reflective processing (type-2: generally slower and it requires controlled reasoning under the use of working memory; Evans & Stanovich, 2013) and the impact on exercise behavior. According to the ART, external (e.g., seeing somebody jogging) or internal stimuli (e.g., thinking of the intention to do more exercise) will trigger the automatic affective type-1 process and activate spontaneous mental associations with memories of exercise. These automatic associations rely on mental associations between the concept of “exercise” and other semantic concepts in memory. It is believed that any activation of the “exercise” concept will automatically reactivate associated concepts (e.g., “displeasure,” “sweat,” “exertion”). Determined by the relative strength and type of activated associations (e.g., “running” and “displeasure”), an automatic affective valuation follows. The affective valuation emerges from somato-affective bonds that formed through one’s past experiences with exercise (e.g., the experience of shortness of breath during a run). These bonds are re-actualized during the automatic processing of the exercise-related stimulus.

According to the ART, the automatic affective valuation includes core affective feelings of pleasure or displeasure that arise directly from the body. This relates to the definition of core affect as a “neuro-physiological state consciously accessible as a simple, primitive, nonreflective feeling most evident in mood and emotion but always available to consciousness” (Russell &

Feldman Barrett, 2009, p. 104). Core affect can be dimensionally classified according to its affective valence (positive–negative) and level of arousal (activation; Russell, 1980). The affective valuation provides the basis for a reflective evaluation (type-2 process; e.g., rational reflection about personal values and expected consequences of exercising) in a way that it can color subsequent reasoning, especially when self-regulatory resources are available. The type-1 process is also connected with a direct impulse to change one’s actual state of physical inactivity; the type-2 process can result in divergent or concurrent action plans.

Recent empirical studies have investigated aspects of automatic processes very similar to the way they are defined in the ART. For instance, several independent studies have shown that those who exercise more have stronger positive automatic associations with exercise compared to those who exercise less (for systematic reviews see Cheval et al., 2018, and Schinkoeth & Antoniewicz, 2017). Automatic associations were shown to be related to exercise decision preferences (e.g., Brand & Schweizer, 2015; Zenko & Ekkekakis, 2019). Activated automatic associations with exercise have been shown to lead to self-imposed physical load in a brief exercise session immediately after the activation (Antoniewicz & Brand, 2016). Consistent with this, the more negative the automatic associations were, the less future exercise behavior was reported by participants (Eves, Scott, Hoppé, & French, 2007).

Very few studies have tried to approach the automatic affective valuation of exercise and its affective core, as defined in the ART, so far. One study relies on data from the Affective Misattribution Procedure (AMP; Payne, Cheng, Govorun, & Steward, 2005) and found that indoor fitness center exercisers had more positively valenced affect after subliminally presented fitness center primes, compared with participants who preferred to exercise in different settings (Antoniewicz & Brand, 2014). Core affect as a neuro-physiological state is accompanied by activity patterns in the autonomic nervous system (ANS), as well as facial changes (Russell, 2003). Two more recent studies (Brand & Ulrich, 2019; Schinkoeth, Weymar, & Brand, 2019) used approaches with biometric data to assess these psychophysiological and behavioral changes associated with the arousal and valence of the automatic valuations affective core. Both studies play essential roles in the empirical study presented here (study descriptions below).

This study aims to disentangle and relate to each other the ART’s two type-1 process components, i.e., automatic associations and affective valuation of exercise. Accordingly, it is necessary to have tests that allow the separate measurement of these two constructs.

1.1. Automatic associations with exercise-related stimuli

Automatic (evaluative) associations between the mental concept of “exercise” and positive or negative attributes (e.g., “pleasure” and “displeasure”) are often referred to in the literature as automatic affective evaluations of exercise (e.g., Conroy & Berry, 2017; Rebar et al., 2016). The majority of studies that have investigated automatic associations with exercise have used variants of the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) to measure these associations (Cheval et al., 2018; Chevance, Bernard, Chamberland, & Rebar, 2019; Schinkoeth & Antoniewicz, 2017).

The standard version of the IAT (Greenwald et al., 1998) uses stimuli from a category with two complementary objects of evaluation (e.g., the target concept “exercise” and the comparison concept “physical inactivity,” with words like “training,” “workout,” “gym,” and “read,” “sit,” “sleep” as word stimuli) and an evaluative category with the two concepts “good” and “bad” (e.g., “pleasure,” “joy,” “fun,” and “terrible,” “disgusting,” “sad” as word stimuli). Study participants have to sort the stimuli presented on a computer screen as fast and accurately as possible to their respective concept by pressing a key on the keyboard, in a test setup in which two concepts from the two categories share the same response key (e.g., “exercise” and “good” paired on one response key, and “physical inactivity” and “bad” on the other). Combinations of concepts vary across test blocks. The test rests on the assumption that those who have positive associations with exercise will sort exercise-related stimuli faster when “exercise” and “good” (vs. “exercise” and “bad”) share the same response key because the response is compatible with their mental associations.

Although it is known that IAT scores can be considered as only partly automatic (Gawronski & De Houwer, 2014), today the IAT is almost regarded as a standard method for measuring automatic associations. Some meta-analyses support the validity of the IAT (e.g., criterion-related validity: Greenwald, Poehlman, Uhlmann, & Banaji, 2009; and convergent validity: Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005), and other reviews have reached more skeptical conclusions (e.g., Schimmack, 2019) with regard to whether the test can predict individual differences in behavior.

1.1. Heart rate variability as a somatic correlate of the affective valuation of exercise

Peripheral correlates of core affective feelings can be measured on the somatic level as activity patterns in the ANS, for example, as changes in heart rate (HR; e.g., Russell, 2003) and HRV (Koval et al., 2013). HR is a somatic indicator of the combined regulatory processes in both

divisions of the ANS, i.e., the sympathetic and parasympathetic systems. Higher HR often occurs when the activity of the sympathetic system is higher than parasympathetic activity, but coinhibition or coactivation of the two divisions can occur as well (Berntson, 2019). Hence, an affective stimulus can produce an accelerated, decelerated, or even unchanged HR response depending upon which activational input is larger (Berntson, Cacioppo, & Quigley, 1991). Empirical studies investigating links between affect and changes in HR have found inconclusive results in consequence (Brouwer, van Wouwe, Mühl, van Erp, & Toet, 2013; Cacioppo, Berntson, Larson, Poehlmann, & Ito, 2000).

HRV is another candidate for the investigation of affective components at the somatic level. It is defined as the variation in the periods between successive heartbeats. Evidence suggests that HRV is a valid measure of parasympathetic (vagal) activity when respiration rate and depth are sufficiently controlled. According to the neurovisceral integration model (Thayer & Lane, 2000), reactivity in HRV (phasic HRV) can be interpreted in terms of the self-regulation of affect via prefrontal–subcortical routes (Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012).

To our knowledge, only one study has so far analyzed HRV reactivity to investigate individual differences in participants' affective responses to exercise-related stimuli (Schinkoeth et al., 2019). In that laboratory study, participants were confronted with exercise-related and neutral control pictures, while their HRV was continuously recorded. Ratings of affective valence and arousal of all exercise-related and control pictures were measured with self-assessment manikins (Bradley & Lang, 1994). The participants' habitual exercise volumes in everyday life were obtained via self-report. Results indicated that those who reported less exercise and evaluated the exercise-related pictures as less pleasant showed a decrease in HRV in response to exercise stimuli. The authors suggested that the observed HRV reactivity could be interpreted as a somatic component of the affective valuation of exercise.

1.2. Facial expression analysis and the affective valence of the automatic valuation of exercise

The valence of affective feelings is sometimes associated with characteristic facial action (e.g., Cacioppo et al., 2000; Lang, Greenwald, Bradley, & Hamm, 1993). This has often been measured with facial electromyography (EMG; e.g., Cacioppo et al., 2000). Viewing unpleasant pictures, for example, from the international affective picture system database (IAPS; Lang, Bradley, & Cuthbert, 1997) has been shown to increase corrugator (“frown-muscle”) activity. In contrast, viewing pleasant pictures prompted zygomatic (“smile-muscle”) tension (Lang et al., 1993).

Recent technological innovations allow the automatic computerized coding and analysis of facial actions in the whole face from video recordings (Kulke, Feyerabend, & Schacht, 2018; Timme & Brand, 2020).

To the best of our knowledge, only one study to date has used automatic facial expression (FE) analysis as a means to identify the valence of inter-individually different automatic affective valuations of exercise (Brand & Ulrich, 2019). There, participants worked through an emotional Stroop task, in which they were asked to respond to exercise-related and control stimuli with either a positive (smile, pleasure) or a negative (frown, displeasure) expression on their face depending on how the respective stimulus was presented. It was hypothesized that participants are faster in giving compatible responses (e.g., if someone who doesn't like exercise has to react with a frown to an exercise-related photo) than in giving incompatible responses (e.g., if the same person has to react to the same picture with a smile because it was presented differently). Results showed that the participants who reported lower exercise volumes and a more negative reflective evaluation of exercise were faster in giving frowns after exercise-related pictures (compared with those who exercised more). The authors interpreted this finding as evidence for a negative automatic affective valuation on reminders of exercise.

1.3. This study

With the present study, we aimed to empirically analyze the relationship between the two components of the type-1 process (automatic association and affective valuation of exercise) postulated in the ART (Brand & Ekkekakis, 2018). We used different measurement methods for these components in an effort to avoid common method bias (Podsakoff, MacKenzie, & Podsakoff, 2003). Automatic associations were assessed with a reaction time-based test (a recoding-free variant of the single-target IAT; Brand & Utesch, 2019). Two separate measures were used to identify the participants' automatic affective valuations of exercise. The somatic component of the affective valuation was addressed by the HRV reactivity test of Schinkoeth et al. (2019), and the affective valence of the reaction was evaluated with the FE task of Brand and Ulrich (2019). We hypothesized that more negative (vs. positive) automatic associations with exercise would predict more negative (vs. positive) affective valuation of exercise, as reflected in experimentally induced HRV reactivity as well as in the affective valence compatibility–incompatibility effect in the FE task. It was furthermore expected that individuals with a more negative (vs. positive) automatic response to exercise would report exercising less (vs. more) often in their everyday lives.

2. Materials and Methods

2.1. Participants and study sample

We sampled data from 107 individuals ($M_{\text{age}} = 25.9 \pm 4.5$ years old, 64 female) who were recruited on a university campus and asked for participation (without applying preselection criteria) after full disclosure of the study aim and measurement procedures. All participants gave written informed consent. Measured data from 38 participants ($M_{\text{age}} = 27.2 \pm 4.9$ years, 23 female) could not be used in our main analyses for different technical reasons: technical malfunction during video recording of the face ($n = 1$), errors in algorithmic identification of a face for facial action analysis ($n = 5$), more than 20% incorrect reactions in the facial expression task ($n = 19$), and technical malfunction during heartbeat recording ($n = 13$).

The data subjected to statistical analysis for hypothesis testing (study sample), therefore, included data from 69 young adults ($M_{\text{age}} = 25.3 \pm 4.2$ years; 41 female). There were no significant differences between the excluded subsample and the study sample in any of the main study variables. However, the participants in the study sample were slightly younger than those in the excluded subsample, $t(105) = 2.15$, $p = .034$, $d = 0.43$.

2.2. Automatic associations with exercise

The participants' automatic associations with exercise were assessed with a recoding-free (RF; Rothermund, Teige-Mocigemba, Gast, & Wentura, 2009) variant of the single-target IAT (STIAT; Bluemke & Friese, 2008). This test is the object of ongoing development in our working group, but a preliminary version of it was presented recently at a conference (Brand & Utesch, 2019). In the RF-STIAT, participants are asked to sort exercise-related target stimuli (exercise words: pulse, breathing, sweating, exertion, muscles, endurance) and attribute stimuli (positive words: pleasant, great, super, awesome, wonderful, gorgeous; negative words: unpleasant, annoying, bad, awful, horrible, terrible) as fast as possible to the target concept "exercise" (exercise-related stimuli), or "good" and "bad" (attribute stimuli). The sorting task consisted of pressing the keys "E" or "I" on the computer keyboard. RF variants of the IAT aim to eliminate recoding effects (Rothermund et al., 2009) by random trial-to-trial alteration of target-compatible and target-incompatible trials. In target compatible conditions, the target concept and "good" are on the one side, and the control concept and "bad" are to the other side, for those who have positive associations with the target concept; in target-incompatible trials the control concept and "good" are to the one side, and the target concept and "bad" are to the other side, for those who

have positive associations with the target concept. The evaluative concepts remain constantly assigned to one side (e.g., “positive” is left or right; inter-individually randomized) whereas the target concept (here: “exercise”) randomly switches between left and right. We calculated and used the G-score (Richetin, Costantini, Perugini, & Schönbrodt, 2015), which represents a robust, scale-invariant, nonparametric measure of automatic associations. This score relies on ordinal information (percentiles of the participants’ response latencies) and represents the difference between the means of the Gaussian rank latencies in the two test blocks. It drastically reduces the bias of outliers. Spearman-Brown corrected split-half reliability of this test score in our sample was $r = .57$, and thus very similar to those reported in previous studies (e.g., Raccuia, 2016).² Fast responses in compatible pairings indicate a strong association between the concept of “exercise” and the evaluative attribute “good” and results in a high positive G-score.

2.3. HRV reactivity

The procedure described in Schinkoeth et al. (2019) was used for the measurement of HRV reactivity. It consists of 14 exercise-related pictures and 14 affectively neutral control pictures from the IAPS (Lang et al., 1997; e.g., household items like an electric socket, a teaspoon, a chair). The exercise-related pictures depicted exercise of differing intensity, e.g., football, hip-hop dancing, and tennis (without showing faces or other obvious display of affect) and exercise equipment, such as, a badminton racket with a shuttle, a high-jump landing pad. The pictures were taken from online stocks and selected according to recommendations of Rebar et al. (2016). Heartbeat and interbeat intervals were measured with a Polar RS800 (CX) heart rate monitor and a chest belt sensor. Data preprocessing and score calculation was performed with Kubios HRV software (v3.0.0). The root mean square of successive differences between normal heartbeats (RMSSD) was chosen as the HRV indicator (Schinkoeth et al., 2019). It is a time-domain index of HRV reflecting vagal tone (Thayer & Lane, 2000) and is a valid measure in ultra-short-term recordings, i.e., in periods of between 10 and 60 seconds (Shaffer & Ginsberg, 2017). HRV scores were natural log-transformed to account for skewed distributions prior to further analysis (Laborde, Mosley, & Thayer, 2017). HRV reactivity is the ratio of HRV during exercise-related

² Due to the smaller number of items, the reliability in single-target IATs is typically lower than in standard IATs. Cronbach-alpha coefficients for internal consistency as a measure of the reliability of IATs are usually significantly higher, and are occasionally reported in publications instead of the split-half reliability coefficient. It must be noted however that items (i.e., participants' test responses) in the two IAT conditions (usually: test blocks) are not expected to covary so that internal consistency scores are inappropriate measures for determining the reliability of an IAT score.

stimuli to HRV during neutral stimuli (i.e., dividing HRV exercise by HRV neutral). Potential confounding variables for HRV (e.g., age, gender, smoking behavior, habitual levels of alcohol consumption, and disorders of the cardiovascular system) were assessed, as suggested by Laborde and colleagues (2017), and post-hoc analyses revealed that HRV remained unaffected by these variables.

2.4. Facial expression task

The FE task described in Brand and Ulrich (2019) was used for measuring the affective valence of the participants' automatic affective valuation of exercise. For this we employed the same 14 exercise-related pictures as in the HRV, however. Another difference from the original procedure was that we used gray rectangles instead of pictures representing a comparison concept (physically inactive study work, in Brand & Ulrich, 2019). The reason for not choosing neutral pictures from the IAPS in our study was that we wanted to avoid artifacts due to irritation (e.g., when participants are asked to respond with a smile to usually unvalenced objects like an electric socket; Lang et al., 1997). We assumed that gray rectangles provide a more appropriate baseline for the latency of showing an affective facial expression to affectively neutral stimuli in this case. All exercise pictures and gray rectangles were presented twice in random order for 4 s each, with a 3-s blank screen between them. All stimuli were 900 × 600 pixels in size, had a thin white frame (two pixels), and were presented centered against a black screen. The participants' task was to produce either a smile or a frown as quickly as possible after stimulus presentation, depending on whether the picture was presented upright (symmetric to the borders of the monitor in one trial) or tilted (1 degree to the left or to the right) according to what they had learned in practice trials before the test. Facial responses (latencies in the generation of facial expressions, i.e., smile or frown, after stimulus presentation; error rates in producing the requested facial expression) were analyzed with automated FE coding software (Affectiva Affdex; McDuff, Mahmoud, Mavadati, Turcot, & Kaliouby, 2016; as implemented in the iMotions platform for biometric research). This software detects faces in videos and tracks the movements of 34 facial landmarks (e.g., brow furrow, nose wrinkle, lip pull corner). Data from these facial movements are analyzed and integrated to classify facial actions (here: smile vs. frown). The detection of positive and negative facial expressions by Affectiva Affdex has been shown to be significantly correlated with the results of EMG measures of corrugator and zygomaticus muscle activity (Kulke et al., 2018).

Following the recommendation by Brand and Ulrich (2019), two ratio scores were calculated. For those who exercise more, and who are therefore supposed to like exercise more, responding with a smile is the compatible response. *Smile latency score* is the ratio of average onset time for signs of positive valence in a participant's FE after exercise-related stimuli to the average onset time for signs of positive valence after control stimuli. Scores smaller than 1 indicate that participants are comparably faster to respond with a requested smile after exercise pictures, which is considered indicative of a positive affective valuation of exercise. This applies conversely to *frown latency score*, which was calculated as the ratio of average onset time for signs of negative valence in one's FE after exercise-related stimuli to average onset time for signs of negative valence after control stimuli. Scores smaller than 1 indicate a comparably faster response with a requested frown after exercise pictures. Those who exercise less, and who are therefore supposed to like exercise less, are meant to respond faster to exercise pictures with a frown, because according to their negative affective valuation of exercise, responding with a frown is the compatible reaction for them.

Calculation and analysis of both scores are essential (Brand & Ulrich, 2019) because it is known from earlier studies with emotional Stroop tasks that effects are mainly driven by reaction time delays in the incompatible condition (Pratto & John, 1991). Therefore, in heterogeneous study samples like here, when the rate of individuals with positive or negative affective valuations of exercise is unknown, both response modality scores (frown and smile latencies) must be analyzed.

2.5. Exercise behavior

Exercise behavior was assessed with one item from the International Physical Activity Questionnaire (Hagströmer, Oja, & Sjöröm, 2006). Participants were asked how often in a week they would usually spend time for moderate or vigorous exercise. They indicated numbers of exercise sessions and average duration of sessions by typing their answers in two separate free-text fields presented on the computer screen. *Number of exercise sessions* was used for hypothesis testing because we have learned from participants in our own previous studies that this information can often be remembered more easily (and probably more accurately) than the exact session lengths.

2.6. Procedure

Tests were conducted under controlled conditions in the laboratory. After the participants gave full informed written consent for study participation, they were seated in front of a computer. Participants first completed the RF-STIAT. Then the chest belt sensor for testing HRV reactivity was attached. This test started with a rest measure, for which participants were asked to remain in a quiet sitting position for 5 min in front of the blank computer screen. Heartbeat and interbeat-interval (IBI) data recorded during this period were used to calculate average HR rest and HRV rest. Then the 28 pictures were presented for 7 s each in four blocks (seven pictures randomly assigned to the blocks and in random sequence; block sequence was fixed to “exercise,” “neutral,” “exercise,” and “neutral” for all participants, and blocks were separated by 10-s blank screens; see Schinkoeth et al., 2019). Participants were instructed in advance that they would see exercise-related pictures in order to elicit their personal thoughts and feelings about exercise. After the HRV-related part of the test procedure, the heartbeat recording was stopped. Then the FE task followed. The participants finally gave their personal data (age, gender) and reported about their exercise behavior and potential HRV confounders (e.g., food intake and caffeine consumption).

2.7. Design, test scores, and statistical tests

A single-measurement study with within-subject experimental variation was conducted. Bivariate intercorrelations between all main study variables were analyzed with Pearson correlation coefficients. Means, standard deviations, and correlations between automatic associations, HR rest, log-transformed HRV scores (HRV rest and HRV reactivity), facial action scores (smile latency and frown latency), and exercise behavior (number of exercise sessions) are shown in Table 1. Two separate linear regression path-models with maximum likelihood estimation were calculated for hypothesis testing using the lavaan (0.6-4) package for R. Path model A tested relations between the variables *automatic associations with exercise* (exogenous variable), *HRV reactivity*, *smile latency*, and *number of exercise sessions*. Path model B contained the same variables, except that *frown latency* (instead of smile latency) was included in this model. We interpreted qualitative and descriptive model fit indicators (i.e., χ^2 , p-value, Tucker–Lewis Index [TLI], comparative fit index [CFI], root-mean-square error of approximation [RMSEA], standardized root mean square residual [SRMR], Akaike Information Criterion [AIC], and Bayesian Information Criterion [BIC]) for both models. Recommended thresholds of model fit indices, their interpretation, and use for the evaluation of a model fit are explained in Kline

(2015). Following recommendations by Goodboy and Kline (2017, pp. 72–73), nonsignificant paths were not deleted.

The sequence of measurements in our study reflects the sequence of processes as postulated in the ART (from automatic associations to affective valuation to behavior). To strengthen the argument that the type-1 process under investigation can be considered in this sequence, two reversed models (models A' and B') were fitted as well (i.e., with number of exercise sessions as the exogenous variable).

3. Results

The reported exercise volume per week ranged from zero min to 720 min per week ($M = 166.36$ min, $SD = 167.38$ min). More exercise sessions per week were correlated with lower HR rest and higher HRV rest. Further analyses revealed a high negative correlation between HR rest and HRV rest. Descriptive statistics, together with these and other correlations, are shown in Table 1.

3.1. Path analysis model A [smile latency score]

Model A (Figure 1.a) exhibited good fit to the data, $\chi^2(2) = 2.74$, $p = .254$, TLI = 0.81, CFI = 0.94, RMSEA = .07 (90% CI: .00, .26), and SRMR = .06. The AIC was 180.04, and the sample-size adjusted BIC was 173.63. More negative (vs. positive) automatic associations with exercise predicted an increase (vs. decrease) in HRV during the presentation of exercise-related stimuli ($p = .044$), and this increase (vs. decrease) statistically predicted lower (vs. higher) self-reported values of exercise ($p = .013$). This finding is in line with what we had expected. The regression weight to predict smile latency score by automatic associations remained too small for statistical significance ($p = .078$). The sign of the coefficient refers to the expected direction of the influence: more negative (vs. positive) automatic associations are related to delayed (vs. increased) response times for smiles. Aside from this, and contrary to our prediction, time-delayed (vs. accelerated) smile responses allow the statistically significant prediction of more (vs. less) exercise sessions per week ($p = .031$).

The reverse model A' exhibited insufficient model fit, $\chi^2(2) = 5.61$, $p = .060$, TLI = 0.10, CFI = 0.70, RMSEA = .16 (90% CI: .00, .33), SRMR = .09, AIC = -61.39, and BIC = -67.80 (detailed results included in article supplement).

3.2. Path analyses model B [frown latency score]

Fit indices for model B were $\chi^2 (2) = 1.756, p = .416$, TLI = 1.09, CFI = 1.00, RMSEA = .00 (90% CI: .00, .23), and SRMR = .05, indicating a good fit to the data. The AIC was 177.86, and the sample-size adjusted BIC was 171.36. Again, increase (vs. decrease) in HRV while viewing exercise-related stimuli was statistically predicted by more negative (vs. positive) automatic associations with exercise ($p = .042$), and less (vs. more) self-reported exercise sessions were predicted by this increase (vs. decrease) in HRV ($p = .048$). Although the signs of all the regression weights here were as expected (positive vs. negative automatic associations predict slower vs. faster response times to frown, and these predict more vs. less exercise behavior), the paths between automatic associations and frown latencies after exercise-related pictures ($p = .117$), and reaction time to frown and number of exercise sessions per week ($p = .344$), remained nonsignificant (Figure 1.b).

The reversed model exhibited good global fit to the data ($\chi^2 (2) = 1.88, p = .390$, TLI = 1.05, CFI = 1.00, RMSEA = .00 (90% CI [.00, .23]), SRMR = .05, AIC = -63.26, and BIC = -69.76). However, in this reversed model only one path was significant, indicating that numbers of exercise sessions can predict HRV reactivity ($p = .032$)

4. Discussion

This study aimed to empirically test theoretical assumptions about the automatic and inherently affective type-1 process as defined in the ART (Brand & Ekkekakis, 2018). Hence, we hypothesized that negative (vs. positive) automatic associations with exercise would predict a negative (vs. positive) affective valuation of exercise, and expected that the two indices of affective valuation (i.e., changes in HRV as an expression of the somatic component, and affective valence as measured with the FE task) could be used to statistically predict the participants' self-reported exercise behavior. Not all of the tested hypotheses found empirical support in the data. As hypothesized, automatic associations with exercise predicted HRV reactivity during the viewing of exercise-related pictures, and this HRV reactivity was associated with the number of self-reported exercise sessions per week. The regression weights for the paths between automatic associations and affective valuation as measured with the FE-task were in the expected direction (negative in model A for smile latency; positive in model B for frown latency) but remained statistically insignificant. Frown latency did not significantly predict exercise behavior, and, in opposition to our hypothesis, faster (slower) smiles on exercise-related pictures were correlated with less (more) exercise behavior. We conclude that the measurement of the valence of the affective valuation with the FE task did not work well in this study.

4.1. Automatic associations with exercise, HRV reactivity, and exercise behavior

Participants with negative automatic associations showed an increase in HRV in response to reminders of exercise, and this increase was linked to fewer exercise sessions per week. Vice versa, positive automatic associations with exercise were linked with a decrease in HRV while viewing exercise pictures, and more exercise sessions in consequence. First and foremost, we consider these findings as preliminary evidence for the process postulated in the ART (Brand & Ekkekakis, 2018)—that reminders of exercise trigger exercise-related automatic associations (here: evaluative associations between the semantic concept of exercise and semantic representations of “good” and “bad”) which are interrelated with an instant psychophysiological reaction (see Damasio, 1996). In terms of the ART, we think that the psychophysiological reaction reflects the somatic core of the participants’ affective valuation of exercise (Schinkoeth et al., 2019). Nevertheless, given the correlational nature of the study, the directional relations between the variables must not be over-interpreted. Results of the reversed models (i.e., insufficient data fit in model A' and nonsignificant paths in model B') indicate that the hypothesized sequence for this process in the ART may continue to be accepted, however. The significant relation between exercise sessions and HRV reactivity (in model B') is in accordance with the assumptions of the ART as well. According to Brand and Ekkekakis (2018), experiences with exercise leave mental traces in memory that form or strengthen automatic exercise associations and color the affective valuation of exercise.

The direction of HRV reactivity in this study was different from the one observed in Schinkoeth et al. (2019), however. In this earlier study, participants who reported less exercise, and were therefore supposed to like exercise less, reacted with a decrease in HRV while viewing exercise-related stimuli, and not with an increase as was observed in the study here (to the best of our knowledge, the two studies are the only ones to date that have examined HRV reactivity to exercise reminders). Of note, previous studies outside of exercise psychology, in which psychophysiological reactions to positively and negatively charged affective stimuli were investigated, have shown both an increase and a decrease in HRV (Kreibig, 2010, for a systematic review). Differences in study samples from the two exercise-related studies (Schinkoeth et al, 2019, and the one presented here) might have contributed to the divergent results here: participants in the previous study (Schinkoeth et al., 2019) were on average 1.9 years younger ($M_{age} = 23.4 \pm 5.9$ years; $t(158) = -2.27, p = .025, d = -0.36$) and reported on average 83.7 min more exercise per week ($M = 250.1, SD = 184.7; t(158) = 2.97, p = .003, d = 0.48$).

Aside from these sample differences, phasic changes in HRV have been interpreted in terms of a variety of affect self-regulation processes (e.g., Appelhans & Luecken, 2006; Holzman & Bridgett, 2017; Thayer et al., 2012). For example, increased HRV (as found here for individuals with a presumably negative affective valuation of the exercise stimuli, according to their automatic associations with exercise and self-reported exercise behavior) has been attributed to higher prefrontal control on the heart and facilitating effective emotional regulation (by either reappraisal or suppression; Butler, Wilhelm, & Gross, 2006; Thayer et al., 2012). Other authors have suggested that processes connected with attentional disengagement may have the same effect (Jennings, 1986; Thayer & Lane, 2000). On the other hand, decrease in HRV (as found here for the participants with a presumably positive affective valuation, according to their automatic associations with exercise and self-reported exercise behavior) has been associated with lower vagal impact on the heart (and perhaps a higher sympathetic activation; Thayer et al., 2012), and, for example, with states of approach and avoidance motivation (e.g., preparing for activity; Kreibig, 2010; Wu, Gu, Yang, & Luo, 2019). In our view, therefore, there should be no further speculation about this point here; instead, we posit that phasic HRV reactivity was measurable here and that more research is needed for a better understanding of the probably complex associations with affective self-regulation and motivational impulses.

4.2. Automatic associations with exercise, affective valence of the valuation, and exercise behavior

The results for the affective valence of the automatic valuation as measured with the FE task (i.e., latencies to produce a smile or frown in response to exercise pictures in comparison to control pictures) were not as hypothesized and as it was shown in one previous study (Brand & Ulrich, 2019). Although the directions of the correlations (regression weights) between automatic associations and frown and smile latency scores, and between frown latency and exercise behavior, were as expected, the coefficients remained too small for reaching statistical significance. Above all, a highly counterintuitive correlation between smile latency and exercise behavior emerged (longer reaction times to produce a smile on exercise-related stimuli predicted more exercise episodes per week).

We would like to emphasize that this was only the second study that attempted to approach the affective valence of the automatic valuation of exercise in an FE task. Our inconclusive results underscore the previously reported result that this FE task might need further refinement (see Brand & Ulrich, 2019). These authors also had to exclude 31% of their data due to incorrect

facial responses by the participants, and they concluded that this emotional Stroop task might be too demanding for many people. In our study here, we had to exclude 18% of the participants for the same reason. Other tests (for example, the AMP; Payne et al., 2005) may be more appropriate for future measurements of the affective valence of study participants' automatic valuation of exercise.

4.3. HRV reactivity and affective valence of the automatic valuation

Although this result should not be overinterpreted due to the difficulties of measuring affective valence with the described FE task, it should be noted that the somatic core of the affective valuation (HRV reactivity) and affective valence (smile and frown latency scores) were uncorrelated. In our view, this suggests that the two indicators indeed represent two different aspects of the automatic affective valuation of exercise (see Schinkoeth et al. [2019], who reported a similar result that valence ratings with the self-assessment manikin test and HRV reactivity were uncorrelated as well). Whereas HRV reactivity might be indicative of (peripheral) psychophysiological activation due to cortical and subcortical processes, the valence of the core affective feeling associated with the affective valuation might be completely independent of it (see Kreibig [2010] for results indicating that affective feelings can be reported without concomitant autonomic changes).

4.4. Study limitations and recommendations for future studies

The number of cases with technical malfunctions was high in this study. As already noted, the FE task might especially require further refinement, or it should be replaced by another test. The final sample consisted of data of only 69 participants. This small sample size may have affected statistical power and the models' fit indices in the path analyses. Small sample sizes can lead to higher χ^2 bias and RMSEAs (Jackson, 2003). In future studies, our findings should be replicated using larger samples. Furthermore, exercise behavior was assessed by self-report. It is known that individuals tend to overrate their exercise behavior in such self-assessments (Duncan, Sydeman, Perri, Limacher, & Martin, 2001). Future studies, especially those that will then focus even more on the links between type-1 processes and exercise behavior, might employ a more objective test of exercise activity, for example, by using physical activity accelerometers. Last but not least, the participants in our study were asked about their past exercise behavior. The ART, however, makes assumptions about the mental processes at the very moment when an exercise-related decision takes place. To stay even closer to the assumption of the ART, future studies might

apply designs such that the automatic affective processes can be measured shortly before or right in the moment of an exercise-related decision.

5. Conclusion

This study showed that negative automatic associations with exercise were linked with a somatic reaction (increase in HRV) that was triggered by watching exercise-related pictures. We suggested understanding this reaction as one somatic aspect of what has been defined as the affective valuation of exercise in the ART (Brand & Ekkekakis, 2018). In our view, this study represents a first but successful attempt to disentangle the two components of the ART's type-1 process. The findings must not be over-interpreted as confirmation of the ART per se. It has been repeatedly pointed out (e.g., Brand & Cheval, 2019; Rhodes, McEwan, & Rebar, 2019) that a greater variety of theoretical and methodological approaches would be necessary to further develop our current understanding of exercise motivation. We hope that the findings presented here represent progress in this direction. Furthermore, through the combination of two reaction time-based measures with different response modalities, one physiological measure, and self-reports, we have tried to avoid common-method bias. The study might, therefore, in addition, offer an outlook on an exercise psychology that no longer predominantly relies on self-report data to examine its constructs.

6. Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

7. Author Contributions

MS conceived the study design with the help of RB. MS performed the statistical analyses and wrote the first draft of the manuscript. RB revised the manuscript.

8. Literature

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9. Figures

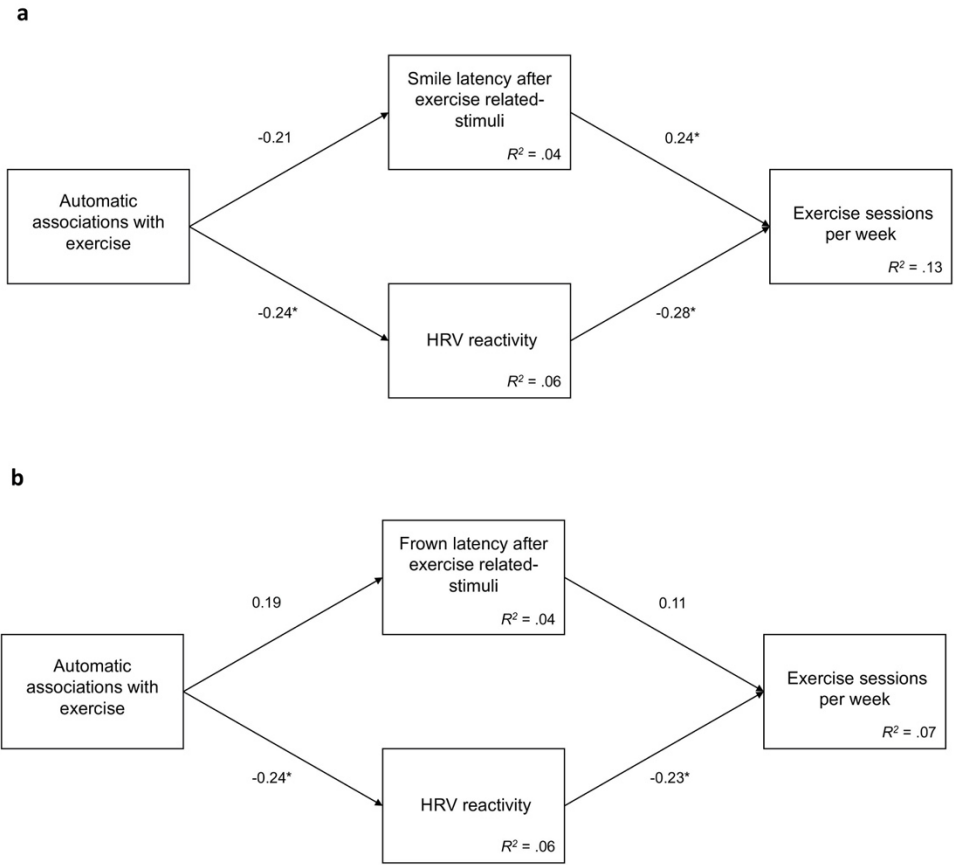


Fig. 1
a: Path analysis model A [smile latency score]; *b*: Path analysis model B [frown latency score].
 Fit indices can be found in the text. R^2 represents explained variance. * indicates $p < .05$

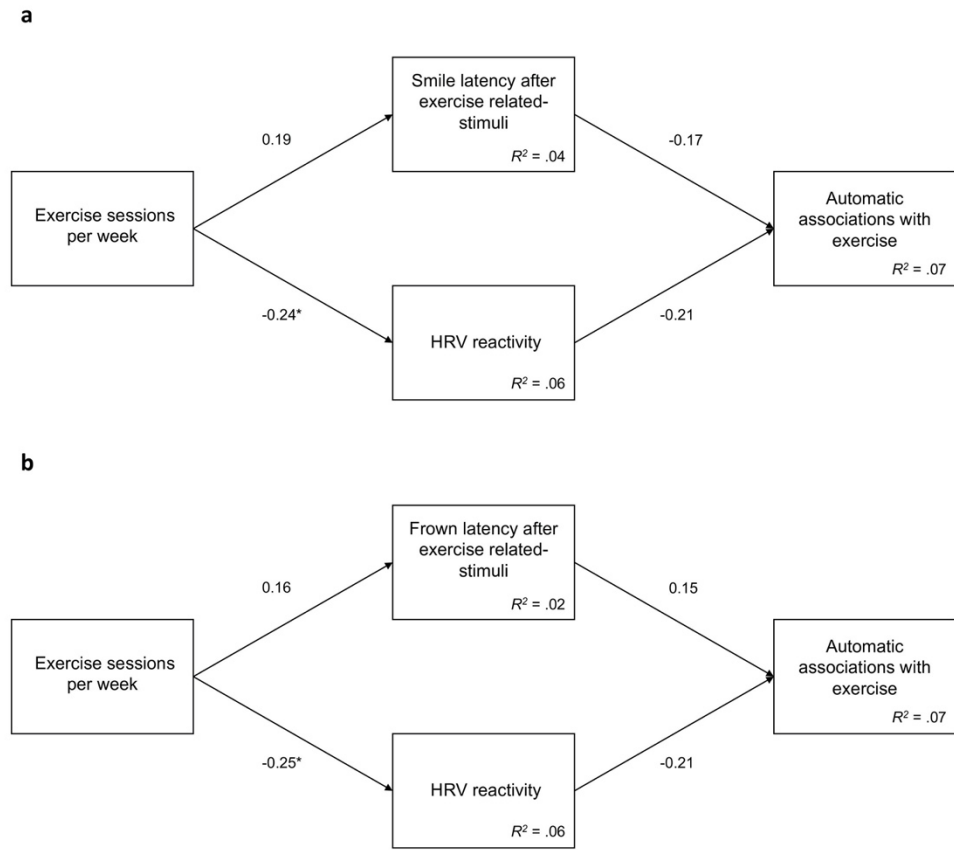


Fig. 2

a: Reversed path analysis model A' [smile latency score]; *b*: Reversed path analysis model B' [frown latency score]. Fit indices can be found in the text. R^2 represents explained variance. * indicates $p < .05$

10. Table

Table 1

Means, standard deviations, and correlations with confidence intervals for the main study variables

| Variable | <i>M</i> | <i>SD</i> | 1 | 2 | 3 | 4 | 5 | 6 |
|--|----------|-----------|-----------------------|------------------------|-----------------------|----------------------|--------------------|--------------------|
| 1 Automatic associations with exercise | 0.04 | 0.30 | | | | | | |
| 2 HR rest | 71.64 | 11.15 | -.03 [-.27, .21] | | | | | |
| 3 HRV rest [log] | 3.60 | 0.62 | .08 [-.16, .31] | -.78** [-.86, -.67] | | | | |
| 4 HRV change [log] | 0.02 | 0.22 | -.24* [-.45, -.00] | .34** [.11, .53] | -.24* [-.45, -.00] | | | |
| 5 Smile latency | 1.03 | 0.13 | -.21 [-.42, .03] | -.04 [-.28, .19] | -.00 [-.24, .24] | .20 [-.04, .41] | | |
| 6 Frown latency | 1.06 | 0.15 | .14 [-.10, .37] | -.10 [-.33, .15] | .06 [-.19, .29] | -.16 [-.39, .08] | .02 [-.22, .26] | |
| 7 Number of exercise sessions | 2.22 | 1.76 | .13 [-.11, .35] | -.29* [-.49, -.06] | .30* [.07, .50] | -.24* [-.45, .00] | .19 [-.05, .41] | .16 [-.08, .39] |

Note. HR represents heart rate and HRV represents heart rate variability. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$