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The relationships among daily exercise, sensory-processing sensitivity, and depressive tendency in Japanese university students

Kosuke Yano[a,*], Kazuo Oishi[b]

[a] Graduated school of Community and Human Services, Rikkyo University, 1-2-26 Kitano, Niiza-shi, Saitama 352-8558, Japan
[b] College of Community and Human Services, Rikkyo University, 1-2-26 Kitano, Niiza-shi, Saitama 352-8558, Japan

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ABSTRACT

Sensory-processing sensitivity (SPS), the trait of being easily affected by a variety of environmental stimuli, is considered to be related to depressive tendencies. SPS can be measured on three sub-scales: low sensory threshold (LST), ease of excitation (EOE), and aesthetic sensitivity (AES). This study investigated the relationships among the levels of SPS, its sub-scales, depressive tendencies, and the frequency of physical exercise in Japanese university students. The participants (N = 275; mean age = 19.4, SD = 1.1) completed questionnaires that included an item on the frequency of physical exercise each week, as well as the Japanese version of the 19-item Highly Sensitive Person Scale and the Self-rating Depression Scale. The results showed that LST and EOE were positively related to depressive tendencies, which were moderated by increasing the frequency of physical exercise. AES was negatively related to depressive tendencies, which was a different result from LST and EOE. Hereafter, longitudinal approaches will be needed to reveal the effects of physical exercise on the relationships between LST or EOE and depressive tendencies.

1. Introduction

1.1. Sensory-processing sensitivity

Sensory-processing sensitivity (SPS) is a trait that differentiates individuals according to the extent to which they deeply process environmental stimuli (Aron & Aron, 1997). Individuals with high SPS have a greater reactivity to internal and external stimuli (Aron, 1996). These stimuli include those with effects on mental life, such as other's emotion and subtle changes in the environment, as well as those with predominantly physical impacts, such as lights and sounds. Individuals with high SPS are easily overaroused and tend to be introvert in novel situations to avoid the excessive stimuli they perceive (Aron & Aron, 1997; Kagan, Snidman, Arcus, & Reznick, 1994). These characteristics have made it difficult to discriminate SPS from other traits, such as neuroticism and introversion. However, Aron and Aron (1997) argued that there were clear differences between SPS and these traits. First, SPS is related to both positive and negative emotions, whereas neuroticism is only related to negative ones. Second, in interviews it has been reported that there were high-SPS individuals who showed traits of extraverts. Additionally, correlation analyses showed distinctions between SPS and neuroticism or introversion in terms of quantitative studies (Aron & Aron, 1997; Grimen & Diseth, 2016; Smolewska, McCabe, & Woody, 2006; Takahashi, 2016).

It is well known that high-SPS individuals tend to have mental health challenges, because of their ease with which they experience overarousal. Many studies have reported that SPS is positively related to perceived stress (Benham, 2006) or social anxiety (Hofmann & Bitran, 2007), and negatively related to self-esteem (Aron, 2010) or self-efficacy (Evers, Rasche, & Schabracq, 2008). The association with depression may be one of the most serious problems for high-SPS individuals (Bakker & Moulding, 2012; Liss, Timmel, Baxley, & Killingsworth, 2005). The relationship between SPS and depression that may be a risk factor for suicide behavior has been examined in terms of psychology and physiology. For instance, regarding physiological studies, it has been suggested that the level of SPS is related to the presence of neurotransmitters such as the 5-HTTLPR short-allele (Homberg, Schubert, Asan, & Aron, 2016; Licht, Mortensen, & Knudsen, 2011) and low densities of dopamine D2 receptor (Chen et al., 2011). Since these factors are related to psychological symptoms such as depression, the level of SPS is thought to be related to depressive tendencies (e.g., Caspi et al., 2003; Reijinders, Ehrt, Weber, Aarsland, & Leentjens, 2008).

Though SPS was originally considered a unidimensional concept (Aron & Aron, 1997), three sub-components are now conventionally used to investigate its relationships with several psychological factors

* Corresponding author.
E-mail address: kosuke.yano1012@gmail.com (K. Yano).

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(e.g., Booth, Standage, & Fox, 2015; Liss, Mailloux, & Erchull, 2008; Smolewska et al., 2006). Those are low sensory threshold (LST), which implies unpleasant sensory arousals, ease of excitation (EOE), leading to feelings of being mentally overwhelmed by environmental stimuli, and aesthetic sensitivity (AES), which implies a rich inner life (Smolewska et al., 2006; Takahashi, 2016). Although a few studies have reported inter-relationships among these sub-components and other psychological factors (e.g., Booth et al., 2015; Liss et al., 2008), further investigations are needed (Gerstenberg, 2012).

1.2. Psychological effects of daily exercise

It is well known that physical exercise can improve mental health, including alleviating such diseases as depression. Many studies on the effects of acute and chronic exercises have been conducted in terms of psychology and physiology. Acute exercise has been shown to be more effective for changing a bad mood than other methods, such as listening to music or being with someone (Thayer, 1989; Thayer, Newman, & McClain, 1994). The activation of neurotransmitters in the monoamine system, i.e., serotonin and dopamine, increases after exercise and decreases depressive tendencies (e.g., Chaouloff, Elghozi, Guezennec, & Laude, 1985; Jacobs, 1994; Nutt, 2008). Many studies have shown that chronic exercise can reduce the levels of stress, and anxiety, as well as depressive tendencies (e.g., International Society of Sport Psychology, 1992). Additionally, it has been shown that the more frequently a person does physical exercise, the better mental health he or she has (Endo, Kanou, & Oishi, 2012; Hassmén, Koivula, & Uutela, 2000). Thus, both acute and chronic physical exercise improves mental health. However, Yano, Kimura, and Oishi (2017) suggested that high-SPS individuals tend to perform physical exercise less frequently, which may be one of the factors for their increased depressive tendencies.

1.3. Purpose of this study

Higher-SPS individuals may generally possess a higher risk of mental problems, such as depressive tendencies (e.g., Liss et al., 2005). However, there have been few studies examining such problems, especially focusing on their sub-concepts. Additionally, the higher SPS a person has, the less frequently he or she does physical exercise to improve his or her mental health (Yano et al., 2017). These findings suggest that increasing the frequency of physical exercise could decrease the levels of depressive tendencies in individuals with high SPS. For this reason, this cross-sectional study investigated the relationships among the frequency of physical exercise, the levels of SPS, its sub-concepts, and depressive tendencies (Fig. 1) in Japanese university students.

2. Methods

2.1. Participants and procedure

Three hundred and thirty Japanese university students provided their consent with pencil and paper in a central location after the purpose and the content of our questionnaire were explained. The 275 completed responses were analyzed (135 from males and 140 from females); the ages of the completing students ranged from 18 to 26 (M = 19.4, *SD* = 1.1). This study was approved by the ethics committee of the authors' university (No. 2016-10).

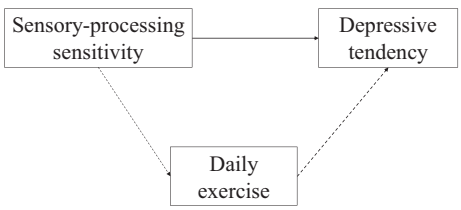

Fig. 1. Hypothetical model of sensory-processing sensitivity, daily exercise, and depressive tendencies
Note. The positive relation is represented by a solid line, and the negative ones are represented by a broken line.

2.2. Measurements

2.2.1. Level of SPS

The level of SPS was measured using the Japanese version of the 19-item Highly Sensitive Person Scale (HSPS-J19; Takahashi, 2016). This is the revised scale of Highly Sensitive Person Scale (Aron & Aron, 1997) for Japanese and consists of 19 items in three sub-scales (Smolewska et al., 2006), i.e., the LST (seven items; e.g., Are you bothered by intense stimuli, like loud noises or chaotic scenes?), the EOE (eight items; e.g., Do you get rattled when you have a lot to do in a short amount of time?), and the AES (four items; e.g., Do you have a rich, complex inner life?) respectively. Each item is evaluated on a 7-point scale from 1 (*Not at all*) to 7 (*Extremely*), with higher scores meaning greater SPS.

2.2.2. Level of daily exercise

The level of daily exercise was evaluated by the frequency of physical exercise per week, with reference to Endo et al. (2012) and Hassmén et al. (2000). The participants were asked, “How often do you participate in physical exercise each week?”

2.2.3. Level of depressive tendency

The Japanese version of the Self-rating Depression Scale (SDS; Fukuda & Kobayashi, 1973) was used to evaluate individuals' depressive tendencies. This scale is based on SDS by Zung (1965), it has 20 items, and each item is evaluated on a 4-point scale, from 1 (*Little or none of the time*) to 4 (*Most of the time*). Higher scores mean greater depressive tendencies.

2.3. Statistical analyses

First, descriptive analyses were conducted to summarize the measurement scores. Second, Pearson product-moment correlation coefficients were calculated to confirm the mutual relationships among the levels of daily exercise, SPS, and depressive tendencies. Finally, the hypothetical model (Fig. 1) was examined using structural equation modeling (SEM). In these analyses, gender was used as a dummy variable, with “0” representing males and “1” representing females (Nozaki & Koyasu, 2013). Statistical analyses were conducted by IBM SPSS (version 21) and IBM Amos (version 21), and the level of significance was 5%.

3. Results

3.1. Descriptive statics and reliabilities for each variable

The mean scores, standard deviations, and Cronbach's alpha coefficients for all variables are shown in Table 1. The HSPS-J19 score for assessing the level of SPS showed good reliability, and the scores of both SPS sub-scales and SDS for assessing the level of depressive tendency showed acceptable reliability, respectively.

3.2. Intercorrelations among all variables

The results of correlation analysis are shown in Table 2. In regard to relationships between gender and each variable, the frequency of physical exercise was significantly related to male gender, whereas the other variables were to female gender. SPS had significantly positive correlations with its sub-scales and depressive tendencies, and a negative correlation with the frequency of daily exercise (all $p < .01$). The sub-scales of SPS showed significantly positive correlations within each

Table 1
Descriptive statics and reliability for each variable.

	n	Mean	*SD*	Cronbach's α
HSPS-J19	275	4.30	0.75	0.85
LST	275	4.24	1.00	0.80
EOE	275	4.24	0.89	0.75
AES	275	4.53	0.92	0.62
SDS	275	2.10	0.45	0.78
Daily exercise	275	2.74	2.36	–

Note. LST = low sensory threshold, EOE = ease of excitation, AES = aesthetic sensitivity, SDS = self-rating depression scale, Daily exercise = frequency of physical exercise.

Table 2
Intercorrelations among all variables.

	1	2	3	4	5	6
1 Gender						
2 HSPS-J19	0.22**					
3 LST	0.15*	0.89**				
4 EOE	0.21**	0.89**	0.69**			
5 AES	0.18**	0.43**	0.19**	0.15**		
6 SDS	0.16**	0.35**	0.40**	0.43**	−0.25**	
7 Daily Exercise	−0.35**	−0.25**	−0.21**	−0.28**	−0.05	−0.33**

Note. Gender: males = 0, and females = 1. LST = Low Sensory Threshold, EOE = Ease of Excitation, AES = Aesthetic Sensitivity, SDS = Self-rating depression scale, Daily Exercise = Frequency of physical exercise.
* $p < .05$.
** $p < .01$.

other, and LST and EOE showed significantly positive correlations with depressive tendencies, while AES showed a negative correlation with them (all $p < .01$). LST and EOE showed significant negative correlations with the frequency of physical exercise (all $p < .01$), while AES showed no significant correlation with it. Additionally, a significant negative correlation was shown between depressive tendencies and the frequency of physical exercise ($p < .01$).

3.3. Relationships among all variables

The hypothetical model shown in Fig. 1 was examined by SEM (Fig. 2). Gender was used as a control variable because of its significant association with all variables (Nozaki & Koyasu, 2013). First, LST was positively associated with depressive tendencies ($\beta = 0.43$, $p < .01$) and negatively with the frequency of physical exercise ($\beta = -0.23$, $p < .01$). Additionally, the frequency of physical exercise was negatively associated with depressive tendencies ($\beta = -0.27$, $p < .01$). Fit indices for structural model were acceptable: $x^2(22) = 47.12$ ($p < .01$), GFI = 0.97, AGFI = 0.92, RMSEA = 0.07. Second, EOE was positively associated with depressive tendencies ($\beta = 0.42$, $p < .01$) and negatively with the frequency of physical exercise ($\beta = -0.31$, $p < .01$). Additionally, the frequency of physical exercise was negatively associated with depressive tendencies ($\beta = -0.20$, $p < .01$). Fit indices for the structural model were good: $x^2(33) = 46.89$ (*n.s.*), GFI = 0.97, AGFI = 0.95, RMSEA = 0.04. Finally, AES showed no significant association with the frequency of physical exercise, while showing a negative association with depressive tendencies ($\beta = -0.53$, $p < .01$). Additionally, the frequency of physical exercise was negatively associated with depressive tendencies ($\beta = -0.31$, $p < .01$). Fit indices for the structural model were unacceptable: $x^2(7) = 54.75$ ($p < .01$), GFI = 0.94, AGFI = 0.83, RMSEA = 0.16. The significance of the indirect effects was tested by using the bootstrap method. The number of bootstrap samples was 5000. The results showed that the indirect effects from LST (95%*CI* = [0.04, 0.12]) and EOE (95%*CI* = [0.04, 0.13]) to depressive tendencies were significant.

These results suggested that LST and EOE in SPS sub-concepts were indirectly related to depressive tendencies through the low frequency of physical exercise in addition to direct relationships, whereas AES was not.

4. Discussion

4.1. Relationships among daily exercise, SPS, and depressive tendency

We examined the relationships among the levels of daily exercise, SPS, and depressive tendencies in Japanese university students using SEM. The results showed the possibility that LST and EOE were related to depressive tendencies through the frequency of physical exercise. In other words, frequent physical exercise could moderate the relationships between depressive tendencies and LST or EOE. Two factors could be considered to explain this possibility. One is the habituation to external and internal stimuli, because the participants who frequently exercise may be generally exposed to strong stimuli, such as loud noises, physical contact, muscle intension, or fast heart rates; alternately, they may acquire several psychological factors that would improve their depressive tendencies. Regarding the former, Aron (1996) suggested that environmental factors could reduce the level of SPS.

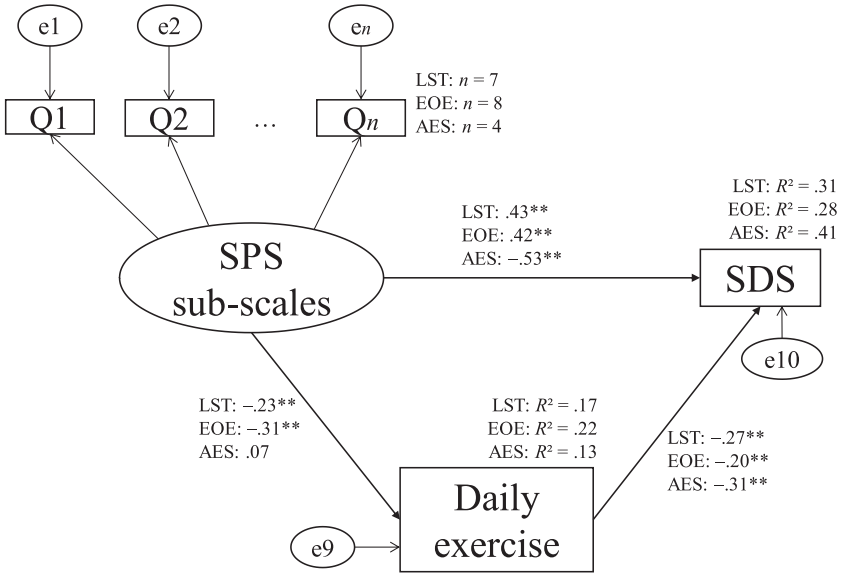

Fig. 2. Structural model for all variables
Note. SPS = sensory-processing sensitivity, SDS = self-rating depression scale, $^{**}p < .01$, Gender is not shown to keep the figure clear, although paths were drawn from it to each observed variable in each analysis.

Additionally, it is generally known that individuals gradually habituate to stimuli in the environment where they live (e.g., Foa & Kozak, 1986). From these findings, it was suggested that frequent physical exercise raised the threshold for sensory processing due to the habituation. On the other hand, it was also reported that the level of SPS is quite stable (Evans & Rothbart, 2007); further, few studies have reported on the relationship between SPS and daily exercise. Therefore, more studies are needed.

In regard to the latter, it is known that the habit of physical exercise is related to the acquisition of various psychological factors. For instance, after a 6-month longitudinal study, Shimamoto and Ishii (2010) suggested the causal relationship that daily exercise enhanced life skills, i.e., individual's abilities to perform adaptive and positive behavior, which enable them to deal effectively with the demands and challenges of everyday life. It has also been suggested that the more frequently a person performs physical exercise, the more social support he or she tends to perceive, i.e., the degree of the perception of being supported by others (Endo et al., 2012). In other words, there is the possibility that increasing the frequency of physical exercise lead to more perceived social support. Additionally, Endo et al. (2012) found the possibility that those who frequently exercise possessed a strong sense of coherence (SOC), which enables individuals to cope effectively with stress by mobilizing resources such as life skills and/or social support. Therefore, it has been suggested that psychological factors acquired by daily exercise are related to the moderation of the relationships between depressive tendency and LST, or EOE. For instance, individuals with high levels of life skills can cope with psychological stress and prevent their depressive tendencies from increasing even if they possess high SPS. Thus, studies are needed that examine various factors, such as life skills and social support.

4.2. Specificity of AES

In this study, correlation analysis and SEM showed that AES included different characteristics in reliability and the association with depressive tendencies from LST and EOE. Former studies have frequently pointed out the low reliability of AES (e.g., Liss et al., 2008), i.e., the Cronbach's alpha coefficient of AES was approximately 0.60 (e.g., Liss et al., 2008; Sobocko & Zelenski, 2015), which is roughly similar to that found in this study. Regarding the relationships between AES and depressive tendencies and/or factors related to it, this study found that LST and EOE were positively related to depressive tendencies, as was shown in a former study (Liss et al., 2008). On the other hand, AES has been suggested to represent a positive aspect of SPS, because of its lack of relation to depressive tendencies and its positive relation to SOC (Evers et al., 2008; Liss et al., 2008). The results of the present study, in which AES was negatively related to depressive tendencies, support the above suggestion. As mentioned above, AES is considered to include characteristics that do not match those of the other sub-scales. Further research is needed to enhance the reliability of AES, to reveal further positive aspects of AES, and to support individuals with depressive tendencies, focusing on the positive characteristics of AES.

4.3. Limitations and future directions

This study showed the possibility that increasing the frequency of physical exercise could moderate the relationships between depressive tendency and LST or EOE in Japanese university students. However, several limitations may be pointed out. First, the participants were limited to Japanese university students. Since cultural differences have been suggested to influence social adaptation in high-SPS individuals (Chen, Rubin, & Sun, 1992), it is unknown whether the results of this study can be generalized to the other races and cultures. Thus, further research is needed in various countries and regions to uncover more useful findings. Second, this study did not consider the factors related to SPS (e.g., neuroticism and introversion). Further studies should consider these factors to reveal the clearer relationships between SPS and other psychological factors such as depressive tendency (Jagiellowicz et al., 2011).

Finally, since this study was based on a cross-sectional approach, longitudinal approaches were needed to reveal causal relations precisely. Future studies should pay attention to the following points: (a) individuals with high SPS may feel psychological stress even if they exercise in a group (Takahashi et al., 2016); (b) physical exercises with low frequency of physical contact may be effective for high-SPS individuals to improve their mental health (Yano et al., 2017); (c) brief exercise, such as a brisk walk for 10 min, may be effective to improve psychological mood (Saklofske, Blomme, & Kelly, 1992); (d) as mentioned above, vigorous exercise producing extreme heart rates may be too much for high-SPS individuals. From these findings, physical exercise alone or in a small group with a low frequency of physical contact, such as jogging, table tennis, or yoga could be effective for high-SPS individuals to improve their depressive tendencies. Thus, future longitudinal studies should consider the characteristics of exercise and extend the findings in this study.

Declaration of interest

Conflicts of interest: none.

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