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SOMATOSENSORY AND MOTOR FUNCTIONS IN SMARTPHONE SYSTEMATIC USERS AND NON-USERS

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We investigated the effect of systematic smartphone usage on the motor and somatosensory finger functions in healthy subjects. Seventeen right-handed healthy volunteers participated in the study. A somewhat better finger sensorimotor function was observed in smartphone non-users. Within the group of smartphone systematic users, the amount of smartphone usage negatively correlated with the spatial discrimination threshold in the fingers. These findings suggest that the input method of the device may not be the only factor influencing the sensorimotor function (other structural differences of the input may also contribute), and that frequent use of the fingers might enhance spatial discrimination. The respective studies can help us to understand interaction between the sensorimotor function and tools and give some insight on how newly developed tools may affect the human brain.

Keywords: somatosensory and motor functions, fingers, motor skills, dexterity, spatial discrimination, smartphone.

INTRODUCTION

New technologies and instruments create a new environment for humans, and human behavior can be changed by the use of novel tools. The telephone may be a good example of this. In the past, rotary dial telephones were used, while push-button telephones are common at present. Because the experience and motor learning molds the sensory and motor cortices of the human brain [1], we postulate that the use of novel tools may affect noticeably the respective somatosensory and motor functions.

Smartphones are mobile phones with advanced capabilities, such as data storage and e-mail; most of them look like a handheld computer with phone functions. Because of portability and various convenient features, smartphones are at present frequently used in extensive populations. A touch-screen display is a typical input method in these tools. Smartphone users appear to make more frequent use of their fingers and have to coordinate their activities with different movements than non-users because they utilize their phones throughout the day for various purposes, such as Internet search and chatting. At the same time, non-users use phones only to call and send text messages. Because it seems that systematic smartphone users experience more frequent proprioceptive stimulation due to more frequent handling [2], we hypothesized that smartphone users may improve the respective somatosensory and motor functions in comparison with smartphone non-users.

METHODS

Participants. Seventeen right-handed healthy volunteers (mean age, 19.1 ± 10.6 years; M ± s.d.; six women) participated in this study after 21 healthy volunteers were screened. Four excluded participants were ambidextrous. Twelve participants were systematic smartphone users, while five were qualified as non-users. Smartphone users were defined as those who had their own smartphones during the experiment and used them daily. Smartphone non-users were defined as those who did not own or used smartphones occasionally. All non-users had a mobile phone with a keypad input mechanism.

The handedness of the participations was assessed

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with the Edinburgh Handedness Inventory [3]. The laterality quotient (LQ) was calculated as in previous studies [4, 5]. The LQ scores ranged from –100 (strong left-handedness) to +100 (strong right-handedness). People with LQ≥+60 were considered to be right-handed [5].

Motor Function Assessment. We used a grooved pegboard test (Lafayette Instruments, Lafayette, USA), which is widely accepted to measure the manual dexterity and motor speed [6, 7]. Before the measurement, researchers explained the procedures thoroughly and demonstrated how to insert the pegs. The grooved pegboard had 25 holes (5 × 5 holes) with randomly positioned slots. Participants were asked to insert the pegs with their right hand as fast as they could, from left to right and from top to bottom. After 30 sec, they were asked to do the above again from right to left and from top to bottom, with their left hand. The pegboard time was defined as the time taken to complete the 25 holes with each hand. The task was performed three times for each hand [7, 8], and we calculated the mean pegboard time for each hand and intragroup means.

Somatosensory Function Assessment. To measure the spatial acuity, we used plastic John-Van Boven-Philips (JVP) domes (Stoeling, Wood Dale, USA) and a plastic Baseline® two-point discriminator (Fabrication Enterprises Inc., White Plains, USA) with the index finger of the participants. We selected these two measurements because the task using the JVP domes is a standardized grating task, and two-point discrimination is a common (traditional) method in the clinical practice. The spatial discrimination threshold (SDT) was determined with the JVP domes and two-point discriminator, as described in previous studies [9-11]. Participants were seated comfortably with their eyes closed and held their palms in a supinated position. Dominant and non-dominant hands were tested. The JVP domes are eight plastic domes with gratings of various widths (0.35 to 3.0 mm). Each of 20 domes was applied to the distal fat pad of the index finger for about 1 sec, beginning with the largest groove width and progressing through narrower widths in a predetermined random order, in either vertical or horizontal orientation. The SDT was determined as the smallest dome with which participants achieved a more than the 75% correct response rate. Participants unable to reach the SDT for the largest groove width (3 mm) were designated as having the SDT of 3 mm [10].

The two-point discriminator is a mechanical sliding caliper with a precision of 1 mm, which has two arms (i.e., two points). The points were applied to the distal fat pad of the index finger 10 times. Five measurements were taken, beginning from 0 mm between the two points and progressively increasing until the participants felt both points. Another five measurements were taken while gradually decreasing the width of two points until the participant felt only one point. The two-point discrimination threshold (TDT) was the mean of these 10 measurements.

Statistical Analysis. We used the Fisher exact test to compare a categorical clinical feature (gender ratio) between smartphone users and non-users and employed the Mann-Whitney test to compare the mean values of age and laterality quotient. The sensorimotor functions between smartphone users and non-users were compared by analysis of covariance (ANCOVA), adjusting for age and gender. We performed additional correlation analyses using the Spearman correlation coefficient to assess the association between the smartphone usage and sensorimotor function. In intergroup comparisons, values of $P < 0.05$ were regarded as significant.

RESULTS

Participants. The characteristics of participants were summarized in Table 1. There were no statistically significant differences between smartphone users and non-users in age, gender, and laterality quotient (LQ).

Motor and Sensory Functions of Smartphone Non-Users and Users. There was a shorter pegboard time in smartphone non-users with the right hand ($df = 1$; $F = 11.01$; $P = 0.021$), but there were no significant differences in the pegboard time between non-users and users with the left hand ($df = 1$; $F = 0.38$; $P = 0.565$).

T a b l e 1. Baseline Characteristics of the Participants

Т а б л и ц я 1. Основні характеристики обстежених осіб

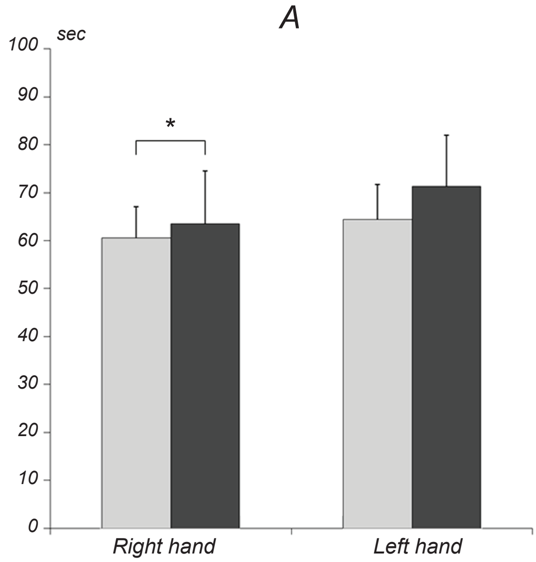
Index	Smartphone non-users (n = 5)	Smartphone users (n = 12)	P
Age (years, mean ± s.d.)	25.4 ± 14.8	16.4 ± 7.7	0.099
Women/Men	3/2	8/4	1.000
Laterality quotient (LQ)	93.0 ± 15.7	90.0 ± 11.3	0.475

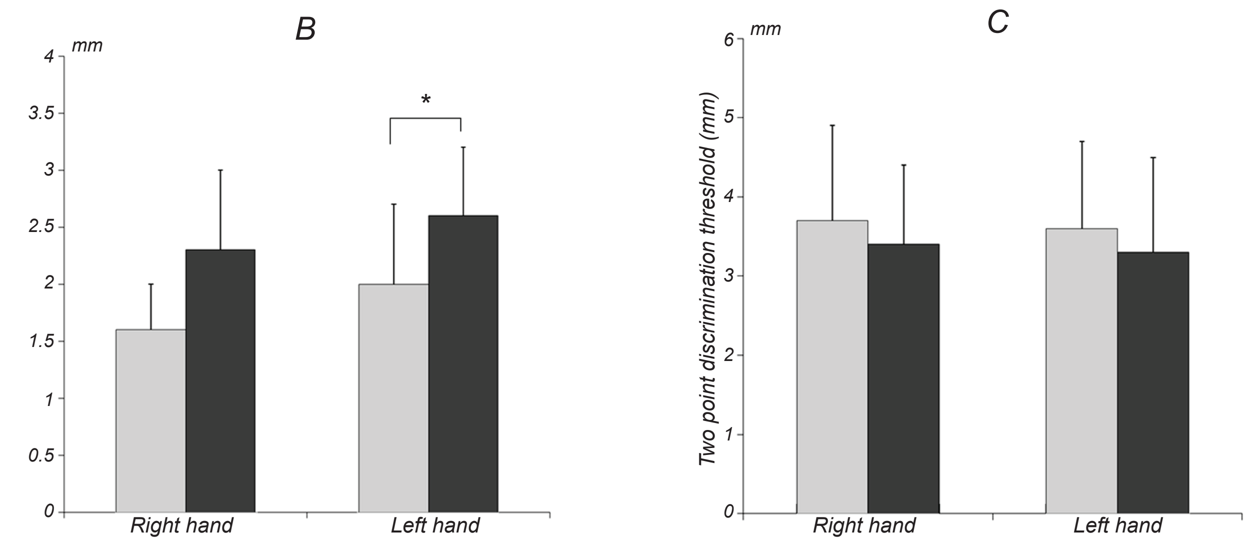
There was a rather clear trend toward the lower SDT in the right hand (*df* = 1; *F* = 4.76; *P* = 0.081), and significantly lower SDT in the left hand (*df* = 1; *F* = 27.21; *P* = 0.003) in non-users. The TDT was similar in the analyzed groups in both hands (right hand, *df* = 1; *F* = 1.42; *P* = 0.287; left hand, *df* = 1; *F*= 0.16; *P* = 0.705). The results are presented in Fig. 1.

Correlation between Smartphone Usage and Motor and Sensory Functions. The amount of smartphone usage was assessed; the self-reported duration of use and daily use was taken into account. The duration of use ranged from 5 to 36 months (mean ± ± s.d., 21.3 ± 10.3 months), and daily use ranged from 2 to 8 h (3.7 ± 2.2 h). The average use was the mean duration multiplied by the average daily use. Overall, neither pegboard time nor TDT correlated with the amount of smartphone use, but SDT significantly negatively correlated with the amount of use (Table 2). Significant or close to significant correlations were noted between the SDT and average daily use in the right (ρ = –0.738, *P* = 0.006) and left hands (ρ = –0.523, *P* = 0.081).

DISCUSSION

We did not find any evidence that a smartphone usage facilitates significantly motor or sensory functions in users. Non-users showed somewhat better motor performance and higher spatial acuity. However, because increased use of smartphones positively correlated with the spatial acuity within smartphone users, we think that frequent use of fingers may somewhat enhance the sensory function, at least within the same instruments.





F i g. 1. Results of motor (A) and sensory (B, C) measurements in smartphone users and non-users (dark and light columns, respectively). A) pegboard time, sec; B) spatial discrimination thresholds, mm, and C) two-point discrimination threshold, mm (see Methods). Right and left are the respective hands. Intragroup means ± s.d. are shown. Asterisks show cases of significant (*P* < 0.05) intergroup differences.

Р и с. 1. Результати вимірювань характеристик моторної (*А*) та соматосенсорної (*В, С*) функцій в осіб, що систематично користуються або не користуються смартфонами (темні та світлі стовпчики відповідно).

T a b l e 2. Correlations between the Motor and Sensory Functions and the Amount of Smartphone Usage

Т а б л и ц я 2.

Indices	Hands	Duration		Daily use time		Total amount of use (duration × daily use time)	
		Spearman correlation					
		ρ	P	ρ	P	ρ	P
Pegboard time (sec)	Right	0.473	0.120	–0.362	0.247	0.039	0.905
	Left	0.382	0.220	–0.362	0.247	0.025	0.940
Spatial discrimination threshold (mm)	Right	–0.121	0.707	–0.738	0.006	–0.554	0.062
	Left	0.352	0.262	–0.523	0.081	–0.186	0.564
Two-point discrimination (mm)	Right	–0.363	0.247	0.075	0.816	–0.169	0.599
	Left	–0.168	0.602	0.189	0.557	0.005	0.987

We hypothesized that smartphone usage might facilitate the motor and sensory functions because we had assumed that smartphones would make people use their fingers much more frequently and accurately, but we failed to prove this hypothesis. The assumption seems to be true that frequent proprioceptive stimulation and finger movements may improve sensorimotor skills, because, among smartphone syatematic users, greater daily use led to a reduced SDT. When comparing smartphone users with non-users, other factors may also contribute. Possible explanations for these results include structural differences between classic mobile phones and smartphones. The attentional requirement to the sensory input might be greater in the non-users. Because of a smaller keypad size, finger tips (narrower finger pads) are used to operate classic mobile phones. More pressure is needed to press the keys of classic mobile phones, and the boundary of each key can be distinguished by touch. These differences may increase the attentional demand required for phone use, which can influence the remodeling of motor and sensory functions [12, 13]. A greater force level of keypad pressure might also affect motor and sensory processing in non-users; as the force level increases, the excitability of the sensorimotor cortex should be increased [14, 15]. Non-users might receive more tactile input from classic phones, which may improve their sensory skills [1]. Because a flat-touch screen has no borders between keys, smartphone users may depend more on visual rather than tactile sensory information. The other explanation is also possible. It can be argued that the smartphone users might be disadvantaged by the tasks that require a different style of movements than they typically use with their phones. Nonetheless, it is less likely because the brain is more activated in complex tasks than in simple ones [16], and the more activated brain may increase its neuroplasticity.

For somatosensory function measurements, we used two instruments, the plastic JVP domes (Stoeling, Wood Dale, USA) and the plastic Baseline® two-point discriminator (Fabrication Enterprises Inc., White Plains, USA). According to our experience, it seems that the JVP dome is more accurate and reliable for the measurement of spatial acuity. These findings are consistent with previous studies. The values of two-point discrimination were highly variable and affected by non-spatial cue [17, 18].

In conclusion, our study did not show that systematic smartphone users have enhanced sensory and motor functions over smartphone non-users, but suggested that, within smartphone users, increased usage of smartphones may improve spatial acuity.

The limitations of our study should be mentioned. First, the mean age of the non-users was greater somewhat than that of the users, although this did not reach the level of statistical significance. Because the sensorimotor response parameters depend on age [18-21], this difference could affect the results of our study. However, we think that this factor is not an issue in our study, because it is well-known that spatial acuity deteriorates with age [18, 21]. If age would have affected our results, the results should be opposite. Besides, we adjusted the age and gender using ANCOVA analysis. Second, we did not measure differences in the mean amount of mobile phone usage between smartphone users and non-users. Frequent smartphone using affected the spatial discrimination function among smartphone users. If smartphone non-users use their phones more often than smartphone users, it could lead to bias in the comparison of the sensorimotor function between smartphone users and non-users. However, we believe that the mean amount of use is much greater in smartphone users because smartphones are used for various purposes (e.g., calls, internet searches, etc.) [2]. Third, the sampling size in our study was rather small. We acknowledge that we need more samples (in particular, non-users) to such experiment. In reality, however, it is getting difficult to recruit smartphone non-users, in particular young people, because more and more people become using smartphones.

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We conducted this study in accordance with the ethical standards described in the Declaration of Helsinki. The study protocol was approved by the Internal Review Board of our hospital. All persons involved in the study gave their written informed consent.

The authors of this communication, Y. M. Lim, Y. R. Kang, and S. Y. Kang, confirm the absence of any conflict related to the comercial or financial interests, relation with organizations or person in any way involved in the research, and interrelations of the co-authors.

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СОМАТОСЕНСОРНА ТА МОТОРНА ФУНКЦІЇ В ОСІБ, ЩО СИСТЕМАТИЧНО КОРИСТУЮТЬСЯ АБО НЕ КОРИСТУЮТЬСЯ СМАРТФОНАМИ

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Р е з ю м е

Ми досліджували вплив систематичного користування смартфоном на соматосенсорну та моторну функції у здорових осіб. У тестах брали участь 17 добровольців-правшів. Серед систематичних користувачів смартфонів сумарна тривалість такого користування негативно корелювала з порогом просторової дискримінації у пальців рук. Цей факт змушує припускати, що метод уводу даних в пристрій може не бути єдиним фактором, що впливає на сенсомоторні функції. Інші технічні особливості також можуть мати вплив; часте використання пальців для оперування може покращувати просторову дискримінацію. Відповідні дослідження можуть допомогти зрозуміти особливості взаємодії сенсомоторних функцій і технічних приладів і по-новому подивитися на те, як нові прилади впливають на мозок людини.

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