2013 IEEE International Conference on Systems, Man, and Cybernetics

# Fundamental Study on Tactile Cognition through Haptic Feedback Touchscreen

Junji Onishi*, Masatsugu Sakajiri*, Takahiro Miura†‡ and Tsukasa Ono*
*Dept. of Computer Science, Tsukuba University of Technology,
Tsukuba, Japan
E-Mail : {ohnishi,sakajiri,ono}@cs.k.tsukuba-tech.ac.jp
†Graduate School of Information Science and Technology, the University of Tokyo,
Tokyo, Japan.
E-Mail : miu@cyber.t.u-tokyo.ac.jp
‡National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba, Japan.

***Abstract*—The touchscreens of recent years are used in variety of purposes, since it can implement a switch to the software that can control easily and cheaply as well as present visual images at the same time. Traditional switch had physical shape and tactile feel, which made it possible to find and operate by touch, but with touchscreen type switch, the texture would be uniform all over like the surface of a glass, so in order to operate the switch, one has to gaze at the image. This presents a huge obstacle to visually impaired or aged persons who cannot easily access visual information. On the other hand, the technology to bring about virtual reality with haptic feedback is beginning to be noticed, and touchscreens with haptic feedback functions are gradually becoming viable. So in this paper, based on the assumption that in the coming days securing accessibility will be achieved by using haptic perception, human's virtual haptic information differentiation accuracy and memory will be examined, using touchscreens with haptic feedback function. The main focus will be on the result of fundamental study carried out with visually impaired persons.**

***Index Terms*—Tactile Cognition, Haptic Perception, Haptic Feedback, Touchscreen, Visual Impairment, Accessibility**

## I. Introduction

The range of use for touchscreen type interfaces such as smartphones and tablet devices has increased rapidly in the recent years. The reasons for this spread can be considered as following two points [1].

- The failure rate and cost can be kept low compared to physical switch as switch function is controlled by software, and switch can be implemented flexibly.
- By combining with images on the screen, intuitive operation can be created, increasing the operability significantly.

Considering the above, the use of touchscreens in even wider range of fields is anticipated in the future, and gradual decrease is expected for the physical switch which tends to break down after repeated switching operation. On the other hand, touchscreens are causing several issues [2]. First of all, unfortunately they cannot provide sufficient accessibility to visually impaired or aged persons who cannot easily obtain visual information. Most touchscreens do not have audio or haptic feedback, and there is no way to specify the location of the icon important for switching operation if visual information is not available. Therefore persons who cannot easily obtain visual information would require help from a sighted person to be shown the locations of objects on the screen, or have to use an interface that has accessible features such as audio guide. User accessibility features such as audio guide can improve on the touchscreen accessibility, but these typically require physical switch or would merely enable the use of limited functions from special gesture operations. Therefore the problem remains that for totally blind, majority of current touchscreen interfaces are not accessible. Second problem is that touchscreens are not suited for switching operations that does not necessarily require images. For example, there are cases such as keyboard operations, car navigations or phone dialing where operating from touch is sufficient, rather than closely observing the image. Also, on a uniform glass surface touch panel, one cannot check by touch whether the switch had operated. Therefore switch function has to be checked on the screen, increasing the strain to the eyes and brain from screen watching. In short, there is an advantage of intuitive operation, but in operations where image is not important, touchscreen has created inconveniences. In particular, letter typing has become considerably less efficient as one can no longer input with touch typing. Incidentally, in December 2012, IBM announced five innovations that will completely change the lives of people in the next five years [5]. In this announcement, following were stated regarding the ability to process human five senses through computers.

- Touch: you will be able to touch through your phone
- Sight: a pixel will be worth a thousand words
- Hearing: computers will hear what matters
- Taste: digital taste buds will help you eat smarter
- Smell: computers will have a sense of smell

Traditionally, numerous researches have been carried out on those five senses for variety of purposes [6], [7]. If one pays particular attention to the part relating to touch, for example they are saying that it will be possible to simulate

978-1-4799-0652-9/13 $31.00 © 2013 IEEE
DOI 10.1109/SMC.2013.717

the tactile sense such as actual texture to persons at remote location by having them touch a screen [4]. Recently, products targeting this goal such as “Sensegs Tixel” from Senseg [13] and “TouchSense” from Immersion [12] have appeared, realizing several hundred types of tactile sensation which can be generated on touchscreen. Tablet devices with touchscreens using the technologies of Immersion have appeared last year, though virtual reality has not been achieved yet. Also, there is no definite guideline set out for making use of these virtual touches for user accessibility yet. Establishment of accessibility for the impaired is still far away. So in this paper, utilizing these haptic feedback technologies that can be integrated into touchscreen, basic study of human haptic feedback information differentiation accuracy and its effect to memory will be carried out, specifically with visually impaired persons as volunteer subjects. This information is necessary in order to consider guidelines for providing environments where persons can operate switches more flexibly. First of all, in section II, the current status of touchscreen accessibility and its problems will be described. In section III, the experiment method on application that was created to measure the human differentiation accuracy for virtual touch will be described. In section IV, using the experiment application, actual testing of haptic differentiation will be carried out by volunteer subjects, and the result and observations will be stated. Finally, conclusion and future prospects will be summarized.

## II. Related work

In the recent years, research on accessibility using touchscreens with haptic feedback function has become very active [8], [9], [10], [11]. These haptic feedback researches can be categorized to several groups based on the haptic feedback that are presented.

First of all, one technology is to provide sensation of clicking with vibrations. This is done by adding vibrator to the device and providing haptic feedback, and some have already been put into practical use. The basic principle of this is a clever use of haptic illusion. There has been many researches done on haptic illusion over the years, and it is said that similar to optical illusion, haptic sense can experience illusion as well. Researches are being progressed to heighten the replication accuracy of textures and shapes by using this mechanism cleverly. It is a promising technique that may result in the arrival of more accurate haptic feedback system in the coming days.

Second method is the technology that has been implemented in Texel E-Sense by Senseg [13]. This is a revolutionary technology that can change uninspiring touchscreen input to dynamic touch input. This provides haptic sensation to the users by controlling the electronic charge in the film pasted on a touch panel, without using mechanical vibrations. The principle is that by combining the strength of electronic charge (voltage) and width (frequency) in variety of patterns, specific haptic sensation is replicated. This is then sent into the control module and is charged on the film. When the charged film is touched in this status, faint electrostatic charge will discharge on the finger tip, which will be conveyed as uneven surface to the finger. The biggest characteristic of this technology is that the generation of noise from vibration can be prevented. There has not been any commercial device using this technology in the market yet, but it is expected that tablet devices with this technology will be available in the near future. The greatest merit of this technology is that no noise will be created from vibration.

As described above, in the recent years a rapid development and spread of haptic replication technologies are happening. Yet in order to utilize them, a common guideline on how to use these virtual haptic sensations for accessibility by the impaired is needed. In order to do so, understanding the mechanism and characteristics of human perception of virtual haptic sensation is important. Using virtual haptic sensation created by latest haptic feedbacks, this paper aims to secure indicators for differentiation accuracy and memory with regards to human haptic perception characteristics, which would be important for applying this technology going forward.

## III. Method

### A. Experimental System

Tablet device MEDIAS TAB UL N-08D from NEC shown on Fig.1 was used to survey haptic differentiation from touchscreens with haptic feedback function. This device is the first commercial machine that used HD Reverb software from Immersion, and by combining with Immersion’s TouchSense 5000 software [12], has the functionality to replicate sensitive haptic sensation with high degree of accuracy. In this paper, to survey the virtual haptic perception accuracy and its characteristics, an application was created, in which ten random haptic sensations would be displayed on the tablet and the users are to select the matching icon out of ten icons prepared in advance on the screen. Fig.2 shows the interface screen of the application created for this experiment. The haptic sensations already programmed in the API of Immersion were utilized for the ten virtual haptic sensation generation. The area (a) of Fig.2 shows the area where random virtual haptic sensations are presented. Area (b) is the ten haptic sensation choices set out upon icons on pre-determined locations. Area (c) is the button for making the final submission, after judging what was touched last in (b) is the same as what was presented in (a). This application links with external database and records the haptic code presented to the test subject, the answered haptic code and the time taken to answer.

### B. Subjects

Ten volunteer subjects including some with amblyopia were involved in the experiment, 1 female and 9 male. Table I shows the details of the volunteer subjects. The age ranged approximately from 20 to 54. All volunteer subjects normally use computer or smartphone every day, ranging from 2 to 8 hours. 8 of the volunteer subjects are amblyopia, and of those, 3 use Braille and find confirming things on screen very difficult, but can just about manage to discern the areas of (a), (b) and (c) in Fig.2 with taking advantage of both the texture

Fig. 1. Test Tablet Device.

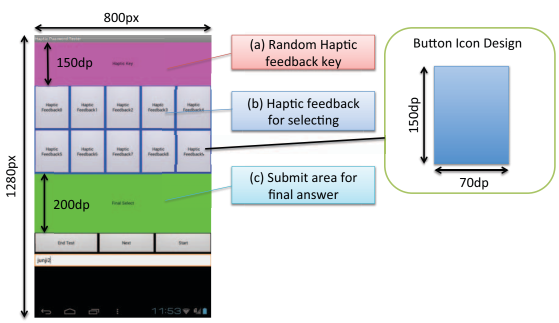


Fig. 2. Appearance of the experimental application.

color and haptic feedback. In addition, none of the volunteer subjects had experience in handling the tablet device used in this experimentation system, and they operated it for the first time in this experiment.

### C. Experiment procedure

Experiments were carried out under below conditions, using following steps.

1) Description of experiment details and software operational procedure
2) To understand how the application is operated, haptic sensation matching tests were run for 10 times
3) Haptic sensation matching tests using the application were carried out for 30 times, and the records were checked in the database.

For operating steps 2 and 3, tests were carried out without any break in between.

## IV. Result and Discussion

### A. Haptic differentiation rate

Fig.3 shows the haptic differentiation rate results by volunteer subjects. This diagram has volunteer subjects on horizontal axis, and quantity is shown on vertical axis, blue bar showing correct and red showing incorrect answers. From this diagram, it can be seen that most volunteer subjects had shown the same haptic choice as what was provided in the test. Volunteer subjects A, C, E, F, I and J had selected several incorrect haptic choices but the main reasons are as below;

1) Could not recognize the correct location of the icon and touched incorrect answer icon by mistake
2) Made a mistake in operating the application
3) Operated with emphasis on answering quickly rather than accurately

Based on above results, it can be seen that in most cases, the accuracy of virtual haptic differentiation is very high. Therefore it can be considered that adding unique haptic sensation to icon selection operation will be useful in confirming screen touch operation. Also, this may be applied in use of haptic differentiation type password input system.

TABLE I
Subjects for the Experimental Evaluation

| Subject | Sex | Age | Eye conditions |
|---|---|---|---|
| Subject A | Male | 44 | sighted |
| Subject B | Male | 26 | Braille character user |
| Subject C | Male | 20 | Minimum readable font size:14pt |
| Subject D | Male | 23 | Minimum readable font size:12pt with a magnifying display |
| Subject E | Male | 20 | Braille character user |
| Subject F | Male | 23 | Minimum readable font size:18pt |
| Subject G | Male | 20 | Braille character user |
| Subject H | Male | 20 | Minimum readable font size:18pt |
| Subject I | Male | 21 | Minimum readable font size:12pt |
| Subject J | Female | 54 | Presbyopia |

### B. Answer time

Fig.4 shows the time taken by each volunteer subjects for each tests. Fig.5 shows the average time with 95% t-based confidence interval for the mean. It can be seen from those two diagrams that while there are some disparity among the volunteer subjects on the time taken to answer, they are only about 3 to 15 seconds, and the time required to answer gets shorter as tests are repeated. The interesting fact is that the time taken to answer gets gradually shorter from about 10th time, and stabilizes between 15th to 30th time. This likely means that haptic sensation allocated to selection icons became partially or fully memorized and it became easier to select the same haptic sensation that was shown in the test. In short, it appears that haptic sensation is recorded in the short term memory of human beings. On the other hand, Fig.6 shows the 10 types of virtual haptic patterns used in the experiment and their average answer time with 95% t-based confidence interval for the mean. These results show that haptic sensations that are relatively easy to short term memorize can be answered in short time, while more difficult ones took longer.

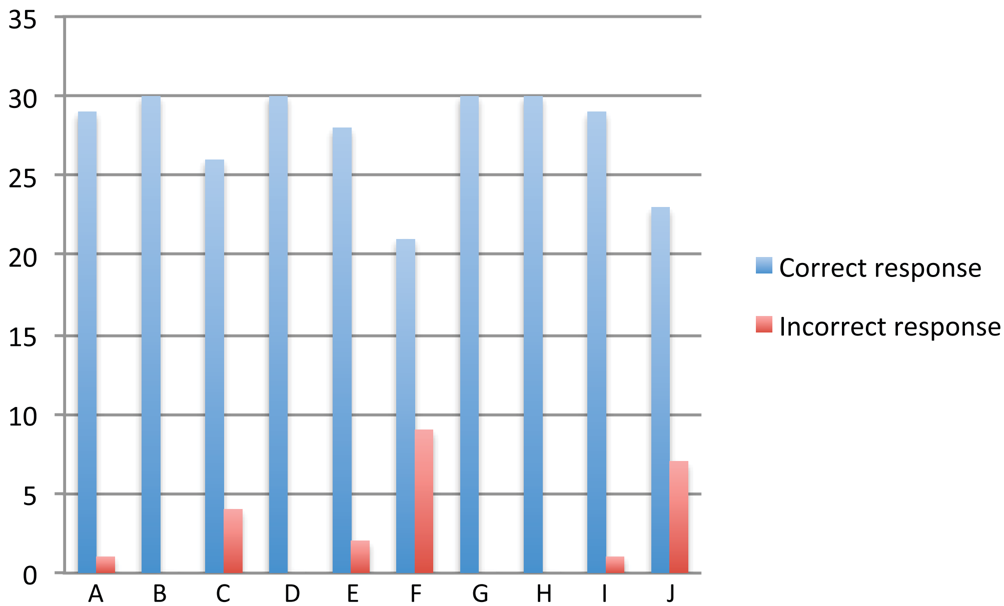


Fig. 3. The number of both correct answers and incorrect answers for each participant

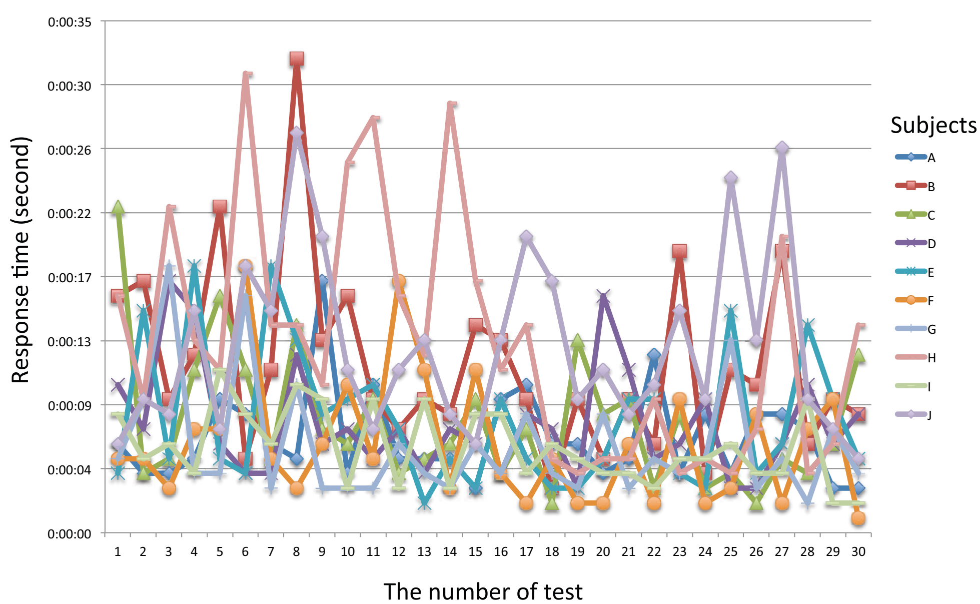


Fig. 4. Response time for each subject

Based on above, one can consider that when using for purposes that requires tactile memory, the selection of virtual haptic pattern becomes important. Over 100 haptic patterns are provided by Immersions API, and creation of unique patterns is also possible. Therefore this suggests that in the coming days, further detailed examinations will be needed with regards to the patterns that can be retained more easily in human memory.

## V. CONCLUSION

In this paper, accuracy and characteristics of human virtual haptic differentiation were examined, in order to obtain indicators for guidelines to be used when visually impaired or Eye-Free operation is implemented for touchscreen switch, using virtual haptic feedback which is expected to advance considerably in the coming days. As a result, it has been proven by experiments that human can correctly differentiate virtual haptic sensations. Also, it has been discovered that depending on virtual haptic patterns, there are degree of memorability to human memory. There is much that is not yet made clear on memorization process of haptic information. However, if one supposes that virtual haptic information can be memorized similar to visual information, many applied uses for visually impaired people can be anticipated, as an alternative sensory data to providing visual information. For example, it would be possible to apply this as alternative information to images that cannot be described in word. There can be other applied uses such as touchscreen utilization that would not depend on images, or in the field of security, use of haptic password device that can avoid the risk of wire tapping or secret filming of words or images is possible as well. There are many promising applied uses in various fields.

More research is planned on the fundamental guidelines for accessibility improvements and new applied uses of touchscreens, by investigating further the relationship between virtual haptic sensations and human perceptions.


## ACKNOWLEDGMENT

This research was supported in both part by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (C), 24531231, 2013 and Tsukuba University of Technology competitive research grants.

The authors are grateful to both Nobuyuki Yamashita and Takeharu Kitagawa, System Devices Division of NEC Corporation, for their providing touchscreen devices and technical materials in the development of experimental software to control haptic feedback on the touchscreen.


## REFERENCES


[1] Miura, T.; Matsuzaka, H.; Sakajiri, M.; Ono, T., “Usages and demands to touchscreen interface: A questionnaire survey in Japanese visually impaired people,” Systems, Man, and Cybernetics (SMC), 2012 IEEE International Conference on , vol., no., pp.2933,2938, 14-17 Oct. 2012.

[2] McGookin, D., Brewster, S. and Jiang, W., Investigating touchscreen accessibility for people with visual impairments, Proceedings of the 5th Nordic Conference on Human-Computer Interaction - NordiCHI 2008, pp.298-307, 2008.

[3] Chubb, E.C.; Colgate, J.E.; Peshkin, M.A., ”ShiverPaD: A Glass Haptic Surface That Produces Shear Force on a Bare Finger,” Haptics, IEEE Transactions on , vol.3, no.3, pp.189,198, July-Sept. 2010.

[4] Bau, O.; Poupyrev, I., REVEL: tactile feedback technology for augmented reality, ACM Transactions on Graphics (TOG) - SIGGRAPH 2012 Conference Proceedings, vol.31, no. 4, Article 89, July 2012.

[5] IBM Corporation, “The 5 in 5”, http://www.ibm.com/smarterplanet/us/en/ibm_predictions_for_future/ideas/ (last viewed:2013/05/12)

[6] Banter, B.: Touch Screens and Touch Surfaces are enriched by Haptic Force-Feedback http://www.walkermobile.com/March_2010_ID_Haptic_Force_Feedback.pdf (last viewed:2013/05/12)

[7] Levin, B. and Woo, A.: Tactile-Feedback Solutions for an Enhanced User Experience http://www.pbinterfaces.com/documents/Tactile_Feedback_Solutions.pdf (last viewed:2013/05/12)

[8] Pathak, A.; Kumazawa, I., “Usability evaluation of touch panel-based mobile device on user interface with multimodal feedback,” Advances in Engineering, Science and Management (ICAESM), 2012 International Conference on , vol., no., pp.703,708, 30-31 March 2012

[9] Martin Pielot, Anastasia Kazakova, Tobias Hesselmann, Wilko Heuten, and Susanne Boll, PocketMenu: non-visual menus for touch screen devices, Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services, No.4, pp.327-330, 2012.

[10] Tinwala, H.; MacKenzie, I.S., ”Eyes-free text entry on a touchscreen phone,” Science and Technology for Humanity (TIC-STH), 2009 IEEE Toronto International Conference , vol., no., pp.83,88, 26-27 Sept. 2009

[11] Toennies, J.L.; Burgner, J.; Withrow, T.J.; Webster, R.J., ”Toward haptic/aural touchscreen display of graphical mathematics for the education of blind students,” World Haptics Conference (WHC), 2011 IEEE , vol., no., pp.373,378, 21-24 June 2011

[12] Immersion Corporation.,TouchSense, http://www.immersion.com/products/touchsense-tactile-feedback/5000-series/index.html (last viewed:2013/05/12)

[13] Senseg, The Senseg Tixel, http://senseg.com/technology/senseg-technology (last viewed:2013/05/12)

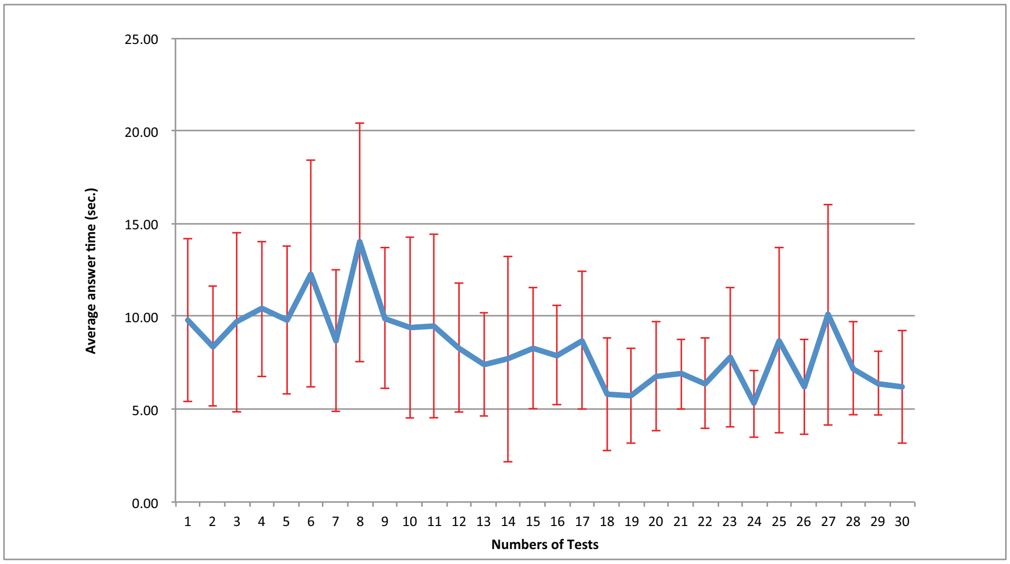


Fig. 5. Average answer time for each test

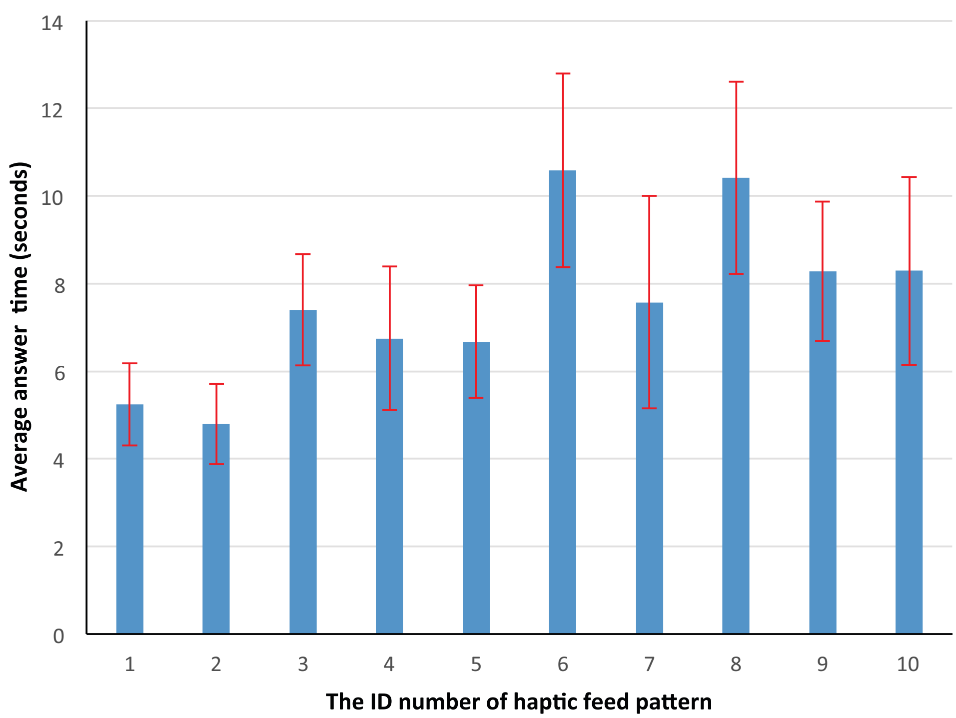


Fig. 6. Average answer time for each haptic feedback pattern.