Does the amount of force used to press a surface alter roughness perception?

Student ID: 2052446

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School of Psychology

University of Birmingham

Birmingham, UK

Abstract

This study investigated the influence of finger force on roughness perception. The experiment had 30 participants, 11 were male and the rest were female. A repeated measures design was used so all participants experienced both conditions. Participants pressed their finger onto seven surfaces and gave each a roughness score. Participants were told to use either a high or low force at the start of the experiment and alternated between the two forces every seven trials until all trials were complete. The results showed that roughness perception was significantly higher ($p < .001$ for surfaces 1-6, and $p = .001$ for surface 7) in the high force condition compared to the low force condition. The results suggest that roughness perception is influenced by the amount of force a person uses to press a surface. There are many implications for this such as increasing our knowledge about how roughness is perceived, contributing to our knowledge about tactile perception and providing useful information for braille keyboard developers, smart phone developers and engineers. Future research should investigate whether there is a difference in how roughness is perceived when pressing a surface using different forces and sliding a finger across a surface using different forces.

Introduction

Tactile perception is part of a “complex human sensory system” that consists of four main components: proprioception (body awareness), mechanoreception (touch), thermoreception (temperature), and nociception (pain) (Schneider and Feussner, 2017). The importance of developing tactile perception through life is highlighted in a review by Bremner and Spence (2017) who illustrated that tactile perception provides people with a sensory scaffold that allows them to perceive their own bodies and their sense of self. Kim and Cho (2014) found that tactile perception stimulates cognitive thinking and influences problem-solving skills in children, further highlighting the importance of developing tactile perception. A study by Goldreich and Kanics (2003) found that blind people have enhanced tactile perception compared to sighted people due to their reliance on tactile perception. This demonstrates how important tactile perception is for blind people.

An article by Ardiel and Rankin (2010) illustrates the importance of tactile perception in human development. In one section of the article, they highlight work by Casler (1965) who found that when institutionalised infants received an additional 20 minutes of tactile stimulation a day, they performed better on development assessments compared to institutionalised infants who did not receive the additional tactile stimulation. The authors later highlight research conducted by Field et al. (1986) and Scafidi et al. (1986) who both investigated the effect that tactile stimulation would have on premature babies. The researchers found that stroking the babies for 10 minutes a day led to better growth and developmental performance compared to controls who did not receive the stroking. They also found that the experimental premature babies were discharged earlier and spent more time awake and active compared to controls. The research illustrated in this article demonstrates that touch plays a vital role in development.

There has been evidence to suggest that developing tactile perception can lead to positive social outcomes. An experiment by Jakubiak and Feeney (2016) compared whether imagined touch support or imagined verbal support was more effective in buffering stress. They found that then when participants imagined touch support, stress was buffered better than when they imagined verbal support or control imaginations. They also found that participants displayed more enthusiasm for the tasks when imagining touch support. This demonstrates the positive influence that developing tactile perception can have on people in a social aspect.

The benefits of tactile perception are further highlighted in an article by Bond (2002). The article emphasised the benefits of touch for infants and parents by stating that massaging infants can play an influential role in helping parents bond with their baby. An article by Feary (2002) further highlighted the benefits of touch therapy, stating that it promotes bonding between parents and their baby. These articles illustrate the importance of tactile perception as it plays a role in creating and sustaining important familial bonds.

Roughness perception is one area that is influenced by tactile perception. Roughness is described as the perception of a textured surface that has elements rising from the substance. Lederman (1972) conducted an experiment to investigate some of the factors that influence roughness perception. Participants ran three fingers across eight surfaces with varying groove widths. The experiment had three different force conditions: the high force condition, the normal force condition, and the low force condition. Participants were asked to give a roughness score for each surface. The results showed that perceived roughness increased with groove width and finger force, suggesting both play a role in roughness perception.

The above experiment found that roughness perception is influenced by groove width. To further investigate this finding, Sathian et al. (1989) conducted an experiment with the aim of examining whether roughness perception increased with groove width. The experiment used surfaces with varying groove widths that participants ran their finger across from behind a curtain. They then assessed the roughness of each surface. The researchers found that participants perceived a surface to be rougher when it had a larger groove width. This suggests that groove width influences roughness perception.

Research has suggested that roughness perception can change depending on the amount of force used to feel a surface. Lederman (1974) investigated this by having participants place their arm on a balance arm and feel surfaces through a curtain. The balance arm is an apparatus that requires a certain amount of force to be applied to it to stay balanced. The amount of force required can be adjusted by adding or removing weights from it. The experiment had three force conditions: the high force condition, the low force condition, and the normal force condition. During the high and low force trials, the balance arm was adjusted, and the participant had to apply either a high or low force on the surface to keep the balance arm steady. During each trial, participants ran their middle finger across eight different metal plates and gave a roughness score for each plate. The results showed that roughness scores were higher in the high force trials compared to the other trials, providing further support for the notion that finger force influences roughness perception.

While there is a large body of research that suggests finger force influences roughness perception, the literature has focused on how roughness perception is influenced when people slide their finger across surfaces using different forces. There is a lack of research on how roughness perception can be altered when pressing a surface using different forces. As a result, there is a gap in people's understanding about roughness perception and this experiment aims to bridge this gap by investigating if pressing a surface using different forces can influence roughness perception.

The results obtained from this experiment will help researchers better understand roughness perception and how finger force influences it. This would be useful to researchers who plan to further investigate roughness perception. Roughness perception plays a key role in engineering and a better understanding of it can be of use to engineers. Moreover, companies that develop handheld items will benefit from these results as they can use this information to make their items more comfortable to hold and to use.

As touch is the least explored of the senses, these results will provide a better overall understanding of tactile perception. This can lead to the development of better braille keyboards for blind people. As well as this, it could help researchers to better understand the link between tactile perception and problem-solving skills. It can also lead to a better understanding of the influence that tactile perception can have in a social setting. Furthermore, understanding the importance of touch in parent-baby bonding and its positive influence on the development of premature babies will be useful information for new parents.

Hypothesis

Roughness perception will increase when the finger force applied increases.

Methods

Participants

This experiment used a voluntary sample as it was the simplest to obtain. There was a total of 30 participants (11 male) aged between 16 and 30. There were no specific requirements to be eligible to take part in this experiment. Participants were presented with an information sheet (Appendix A) that stated the purpose of the experiment and had instructions. They were then given a consent form (Appendix B). Participants were told the true aim of the experiment at the start and so could provide informed consent.

Material

The experiment used a Lazy Susan (Di Luca, 2022) that had seven surfaces with varying groove widths and ridge heights attached to it (see Table 1). There were also two base surfaces, one extremely rough and one smooth which were used to help participants learn the two extreme ends of the scale. All the surfaces had a ridge width of 480µm. The surfaces were made using a 3D printer. The results were analysed using SPSS.

	Ridge height (µm)	Groove width (µm)
Surface 1	536	680
Surface 2	632	1160
Surface 3	728	1640

Surface 4	824	2120
Surface 5	920	2600
Surface 6	1016	3080
Surface 7	1112	3560
Rough base surface	1208	4040
Smooth base surface	440	200

Table 1 Depicts the ridge heights (μm) and the groove widths (μm) of the surfaces used in this experiment.

Procedure

The experiment consisted of two conditions: a high force condition and a low force condition. The experiment had four blocks, each containing seven trials. A single trial consisted of the participant pressing one of the seven surfaces and giving a roughness score. Each condition was assessed twice so there were 28 trials in total. A pilot study had shown that participants found the experiment to be quite tedious if there were many trials. As a result, this experiment had 28 trials to ensure that the participants remained engaged during the experiment. The experiment had a repeated measures design and used counterbalancing to avoid order effects.

At the start of the experiment, participants pressed the upper part of their index finger on the two base surfaces using a high and low force. Participants were told if they were starting with the high or low force condition and alternated between the two forces after each block. A pilot study showed that when participants were told to alternate between a high and low force for each trial, they became confused about which force to use. To counter this problem, participants were made to alternate between forces after each block instead of each trial.

After feeling the two base surfaces, participants pressed the button on the Lazy Susan which rotated and presented the participant with the surface that they needed to press. Participants pressed the surface using the upper part of their index finger and then gave the surface a roughness score ranging between 1 and 10. They repeated this process until all trials were completed. The Lazy Susan was programmed to rotate between the seven surfaces in a random order which was changed after each block.

Analysis

Before analysing the results, a test of normality was conducted to see if the data met parametric assumptions. Table 2 shows that some parts of the data were normally distributed while other parts were not normally distributed. As a result, the data did not meet parametric assumptions.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Surface 1 HF	.322	30	<.001	.772	30	<.001
Surface 1 LF	.412	30	<.001	.648	30	<.001
Surface 2 HF	.303	30	<.001	.821	30	<.001
Surface 2 LF	.214	30	.001	.858	30	<.001
Surface 3 HF	.167	30	.032	.934	30	.061
Surface 3 LF	.179	30	.016	.938	30	.081
Surface 4 HF	.150	30	.082	.929	30	.045
Surface 4 LF	.124	30	.200*	.954	30	.221
Surface 5 HF	.144	30	.114	.960	30	.311
Surface 5 LF	.203	30	.003	.889	30	.005
Surface 6 HF	.129	30	.200*	.950	30	.169
Surface 6 LF	.147	30	.097	.939	30	.083
Surface 7 HF	.112	30	.200*	.936	30	.073
Surface 7 LF	.127	30	.200*	.961	30	.322

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 2 Depicts the results from the test of normality. HF = High Force. LF = Low Force.

The data was analysed using the Wilcoxon Signed Ranks test on SPSS. This is because the data did not meet parametric assumptions, all the participants took part in both conditions, and a difference between the two conditions was being investigated. To conduct the Wilcoxon Signed Ranks test, each participant's average high force roughness score and average low force roughness score for each surface was calculated.

Results

Figures 1 and 2 show the data obtained from this experiment. The figures clearly demonstrate that a larger percentage of participants gave higher roughness scores in the high force condition compared to the low force condition. They also show that while roughness perception increased for each surface in both conditions, the increase is much more prominent in the high force condition.

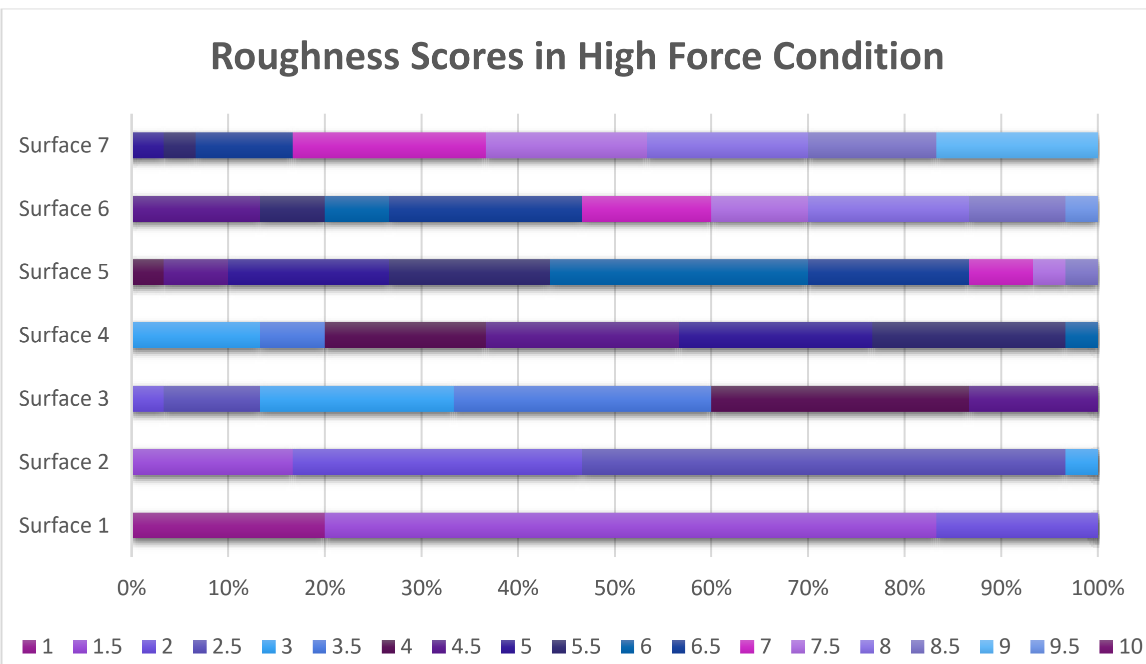

Figure 1 Participants gave roughness scores between 1 and 10 for each surface. This figure shows the percentage of participants that gave certain scores in the high force condition.

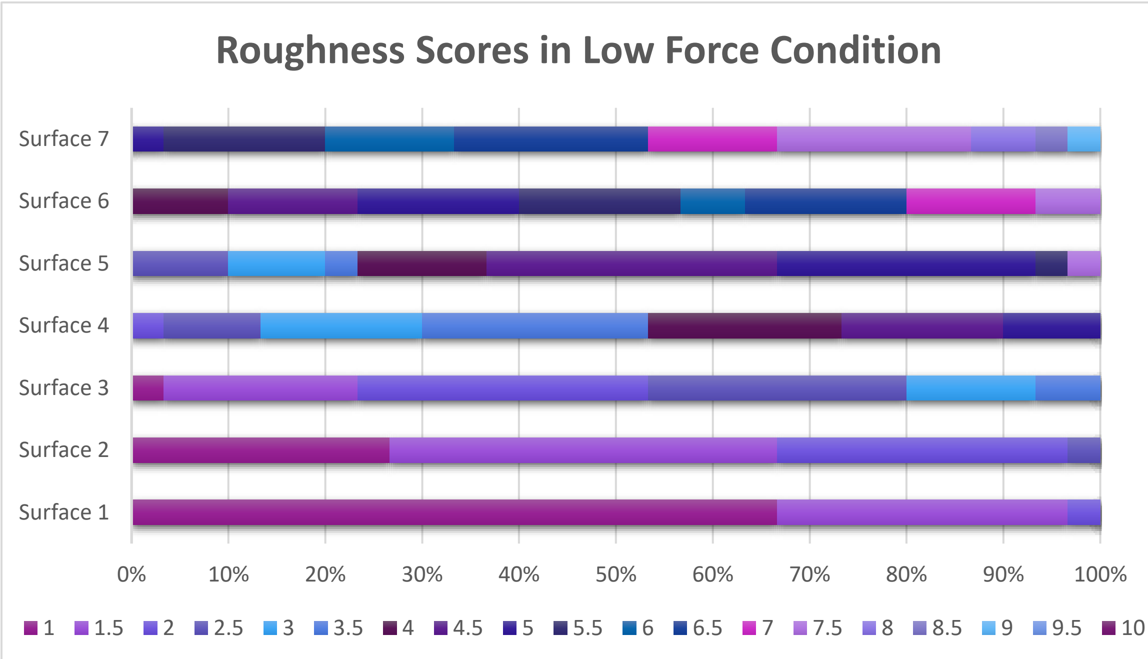

Figure 2 Participants gave roughness scores between 1 and 10 for each surface. This figure shows the percentage of participants that gave certain scores in the low force condition.

Table 3 shows that roughness perception significantly increased during the high force condition for surface one (z = -3.626, p <.001), surface two (z = -4.597, p <.001), surface three (z = -4.571, p <.001), surface four (z = -4.159, p <.001), surface five (z = -4.557, p <.001), surface six (z = -3.518, p <.001), and surface seven (z = -3.255, p = .001). These results support the hypothesis.

Test Statistics[a]

	Surface 1 LF - Surface 1 HF	Surface 2 LF - Surface 2 HF	Surface 3 LF - Surface 3 HF	Surface 4 LF - Surface 4 HF	Surface 5 LF - Surface 5 HF	Surface 6 LF - Surface 6 HF	Surface 7 LF - Surface 7 HF
Z	-3.626[b]	-4.597[b]	-4.571[b]	-4.159[b]	-4.557[b]	-3.518[b]	-3.255[b]
Asymp. Sig. (2-tailed)	<.001	<.001	<.001	<.001	<.001	<.001	.001

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

Table 3 Depicts the output of the Wilcoxon Signed Ranks test.

Discussion

The results obtained from this experiment show that finger force has a significant influence on roughness perception, supporting this experiment's hypothesis. These findings have many implications for future research and people's daily lives. The main implication of this experiment is that it provides evidence to suggest that when a person presses a surface using different forces, their perceived roughness of that surface will change. This addresses the gap in the literature which focused on how sliding a finger across a surface using different forces influences roughness perception but did not investigate if pressing a surface using different forces would have the same influence.

As well as addressing the gap in the literature, the results obtained from this experiment will provide researchers with more information about how people perceive roughness. This information could be of use to researchers who plan to conduct further experiments on roughness perception. The researchers would have to take these findings into account when conducting future experiments on roughness perception. These findings could also inspire researchers to think of other research questions related to roughness perception that need investigating. One aspect to investigate could be comparing if there is a difference in how roughness is perceived when pressing a surface using different forces compared to sliding a finger across the same surface using different forces.

Another consequence of this research is that it can help researchers to better understand touch and how tactile perception works. An improved understanding of tactile perception is something researchers should aim to work towards. This is because tactile perception influences many areas of human life such as problem-solving skills (Kim and Cho, 2014), parent-baby bonding (Bond, 2002; Feary, 2002), and can positively influence the growth and development of premature babies (Field et al., 1986; Scafidi et al., 1986). As well as this, it can have a positive effect on institutionalised infants (Casler, 1965), can reduce people's stress in social situations (Jakubiak and Feeney, 2016), and provides people with a sensory scaffolding that allows them to perceive themselves (Bremner and Spence, 2017). Improved understanding of tactile perception can help better understand how and why tactile perception plays a role in so many different aspects of human life and can lead to the development of methods and techniques to positively influence these aspects.

Furthermore, these findings may be of use for people who develop braille keyboards and other braille systems. This is due to these systems requiring blind people to press their fingers onto the braille patterns to be able to read and write. Insight about how the perception of a surface's roughness can change when pressing that surface using different forces is information that braille system developers could consider during development to create better and more efficient systems.

A further implication of this research is the benefits it would provide to companies that develop smart phones. Smart phones are used by pressing one's finger on the screen to do different things. Knowledge about how a person's perception of roughness can change when they use a different force to press the screen is something companies can consider during development stages to ensure they create a device that is comfortable to use. This could also apply to other companies that specialise in developing handheld items other than smartphones.

Moreover, these findings would be of benefit to engineers. When making decisions about building new structures, engineers will have to take the roughness of materials into account before deciding which material to use. This is because rougher materials wear away easier than less rough materials so engineers will usually avoid the use of rougher materials. Engineers will be better able to assess the roughness of a material if they are informed that pressing materials using different forces will influence their perception of roughness.

A limitation of this study is that there were few trials to examine roughness perception. While the number of trials was decided on to ensure that the participants remained engaged during the experiment, it limited how much data could have been obtained. This should not affect the validity of the data as a large sample size was used which should make up for the small number of trials. However, researchers should still try to address this to be sure that this is the case. To address this, researchers should replicate this study using more trials and should see whether the results from this experiment are replicated. To counter the problem of participants feeling bored or losing interest, the researchers could try spreading the experiment out over several days and conduct a few trials each day.

Another problem with this experiment was that there was no way to control how much force the participants used in the different conditions. It is highly likely that the participants did not all use the same amount of force in the high force condition or the same amount of force in the low force condition. To account for this, researchers should replicate this study while making use of the balance arm used by Lederman (1974) to ensure participants all use the same amount of force when pressing the surfaces in the different conditions. Doing this would increase the validity of the results.

While this experiment does have some limitations, the experiment also has several strengths. As mentioned before, the experiment has a sample size of 30 people which is much larger than the samples used by Lederman (1972,1974) and Sathian et al. (1989). A larger sample size increases the accuracy of the data obtained which makes the results more valid. Furthermore, the conditions were counterbalanced which ensured that the participants did not display order effects. It also minimised the risk of the data being influenced by extraneous factors such as practice. As well as this, the Lazy Susan was programmed to rotate and present the participants with the surfaces in a random order which was changed after every block. Doing this ensured that the participants did not work out which of the seven surfaces they were feeling. It also ensured that the order that participants felt the surfaces in during each block was different, further reducing the likelihood of the participants predicting the order of the surfaces. This was important as it reduced the participant's ability to alter their responses in a favourable way or a way that could sabotage the results.

Overall, this study aimed to investigate whether finger force would alter roughness perception and the results obtained suggest that this is the case. Researchers should try to replicate this study to confirm the reliability of these results. They should also investigate whether roughness perception changes when pressing a surface using more than just two forces. They should make use of a balance arm during these experiments. A final aspect that researchers should investigate is if there is a difference in how roughness is perceived when pressing a surface using different forces and sliding a finger across a surface using different forces.

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Appendix A

Information Sheet

The aim of this study is to investigate whether a person's roughness perception is influenced by the amount of force they use to press a surface. The experiment should take no more than 15 minutes and your data will be anonymous. You are not required to take part in this study.

Instructions

You will press the top part of your index finger on two base surfaces using a high and low force.

You will be told if you will be starting in the high or low force condition.

You will then press a button on the Lazy Susan which will rotate and present you with one of seven surfaces to press.

You will give a roughness score between 1 and 10 for the surface you have pressed.

You will repeat this process for all seven surfaces.

You will then press all seven surfaces again using a different force. If you started in the high force condition, you will now be using a low force and vice versa.

Each condition will be tested twice; there will be 28 trials. You will use a high force for half of these trials and a low force for the other half of these trials.

Appendix B

Consent Form

Your responses in this experiment will remain confidential and will not be associated with your name. You are allowed to stop participating in the experiment at any point should you feel uncomfortable. Should you choose to stop taking part, your data will be discarded, and you will not be penalised for this. Your participation in this study should take no more than 15 minutes. If you have any concerns about this study, please contact me via email:

Uzma Kauser – UXK846@student.bham.ac.uk

I understand that my participation in this experiment is voluntary.
Please circle Yes or No.

I understand that my data will remain confidential and will not be associated with me.
Please circle Yes or No.

I understand that I can withdraw from the experiment at any point and will not be penalised for it.
Please circle Yes or No.

I understand my rights and consent to take part in this experiment.
Please circle Yes or No.

Please sign below to confirm that you would like to take part in this experiment.