Task-Adapted Single-Finger Explorations of Complex Objects

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Abstract. The perception of material/object properties plays a fundamental role in our daily lives. Previous research has shown that individuals use distinct and consistent patterns of hand movements, known as exploratory procedures (EPs), to extract perceptual information relevant to specific material/object properties. Here, we investigated the variation in EP usage across different tasks involving objects that varied in task-relevant properties (shape or deformability) as well as in task-irrelevant properties (deformability or texture). Participants explored 1 reference object and 2 test objects with a single finger before selecting the test object that was most similar to the reference. We recorded their finger movements during explorations, and these movements were then categorised into different EPs. Our results show strong task-dependent usage of EPs, even when exploration was confined to a single finger. Furthermore, within a given task, EPs varied as a function of material/object properties unrelated to the primary task. These variations suggest that individuals flexibly adapt their exploration strategies to obtain consistent and relevant information.

Keywords: Exploratory procedures, haptic perception, active touch.

1 Introduction

The perception of haptics properties of objects plays a fundamental role in our daily lives, whether it's stoking a cat's fur, gauging the weight of a rock, or pressing one's palm on a chair to evaluate its sturdiness. Different exploratory movement patterns are intentionally employed during active touch to perceive different dimensions [1]. The selection of exploratory procedures (EP) is closely linked to the material/object properties and the perceiver's exploration objectives [2, 3]. Previous research has demonstrated that individuals habitually use distinct EPs, to extract perceptual information related to the target haptic properties [1, 4 -5]. For example, to perceive compliance, people tend to indent or apply pressure to the object; for texture perception, they engage in lateral motion, repetitively rubbing their fingers across the surface to discern its texture. In contrast, when judging the shape of an object, they use contour following, with one or more of their fingers or the entire hand tracing along the contour of the object.

Hence, the selection of EP is strongly determined by the target haptic properties one aims to discern.

However, objects often possess many haptic properties beyond the one targeted, which raises the question of whether the properties of an object beyond the primary focus of exploration would influence the selection of EPs. For example, when the primary objective is to explore the shape of an object, would other properties, like its texture or deformability, influence the perceiver's selection of EP when exploring the object? There is limited research on how task-irrelevant object properties modulate exploration behaviours. Klatzky et al. [5] conducted an experiment in which multidimensional objects varying in shape, size, hardness and texture were used, and participants had to sort objects along a designated dimension (e.g., texture). Their results demonstrated that while exploring objects with variations in multiple haptic properties, the utilization of EPs varied according to the specific perceptual task. However, while they confirmed that the task strongly influenced specific EP frequency, they did not investigate whether EP usage also systematically varied with object properties unrelated to the primary aim of exploration.

Therefore, our current study examines how varying object properties unrelated to the primary aim of exploration may affect EP patterns during haptic exploration. However, in contrast to [5], in our experiment, we constrained the exploration to the use of the index finger. While effective executions of many EPs may usually involve coordinating both hands or using the whole hand, several studies have also shown that a single finger usage is adequate for haptic exploration in various tasks and contexts [e.g., 6-8]. It is likely, however, that the single finger restriction may – as a function of task and/or object property - alter EP frequency and/or EP character, a possibility that we will consider below.

Taken together, the goals of our study are to examine the variation in EP usage for two different tasks performed with the same set of objects, that either varied in task-relevant (first goal) or in task-irrelevant properties (second goal). By examining variations in EP usage in the presence of task-relevant and task-irrelevant properties, our study adds to the growing body of literature in haptics research, offering insights into the adaptive nature of haptic exploration strategies, in particular under the constraints of single-finger explorations, which holds potential for real-world application such as robotic explorations and teleoperation. For the first goal, we used a set of objects that varied in both shape and deformability, and we had participants explore and evaluate the similarity of objects based on either shape or deformability. For the second goal, we used data from the set of objects that varied in both shape and deformability and further data from another set of rigid objects that varied in shape and texture. We compared how participants explore and assess the similarity of objects in the two sets based on the shapes.

2 Methods

2.1 Participants

10 participants (5 females, M_{age} = 28yr, SD_{age} = 4.59yr, Range = 21-34) were recruited from Giessen University. All participants but one were right-handed and had no history of motor or cutaneous impairments. All participants had a 2-point discrimination threshold of < 4mm on their right-hand index fingertips. All participants provided informed consent and received compensation of (8€/h) for their participation. The video recordings of 2 participants were excluded from the video analyses due to recording errors or incomplete data sets. This study was approved by the local ethics committee at Giessen University and conducted in accordance with the declaration of Helsinki (2013).

2.2 Aparatus

Participants sat at a table opposite the experimenter. A monitor and keyboard were placed on the experimenter's left to run the experiment and collect participants' responses. The experiment was programmed using Psychopy (version 2022.2.4). During the experiment, participants' hand movements were recorded with a Sony Digital 4K Video Camera (recording 28-bit videos with a resolution of 1920 × 1080 pixels); the camera was placed on a tripod on the left of the table. Each of these stimuli was placed in a 3D-printed tray (65 mm × 65 mm) mounted on the table, and a thin layer of silicone was applied to the interior of the tray to minimise potential displacement during explorations.

2.3 Stimuli

We organised our stimuli into two primary categories: smooth-deformable shapes and textured-rigid shapes. Within each category, we created two subsets labelled as set A and set B, resulting in 4 subsets in total: smooth-deformable set A, smooth-deformable set B, textured-rigid set A, and textured-rigid set B. Each subset consisted of five objects.

The smooth-deformable shapes were cast in 3D-printed moulds. To achieve varying levels of deformability in the stimuli, a two-component silicone rubber solution (Alpa Sil EH A & B) was mixed with different amounts of silicone oil. There were five levels of deformability (least soft - d1: 0.44 mm/N; d2: 0.68 mm/N; d3: 0.79 mm/N; d4: 1.02 mm/N; Most soft - d5: 1.13 mm/N). On the other hand, the textured-rigid shapes were 3D-printed plastic objects covered with different textured fabrics (i.e., t1: corduroy, t2: tweed, t3: velvet, t4: jersey cotton, t5: burlap – note: we randomly assigned a number to each texture, and it bears no relation to nature of the texture itself).

Across all sets (set As and set Bs), the shapes were defined by varying numbers and prominence of concavities and convexities, and these remained consistent across all sets (labelled S1 to S5). However, within each set, we varied the texture and deformability levels to create different texture×shape and deformability×shape combinations across set A and B. (see **Fig.** 1).

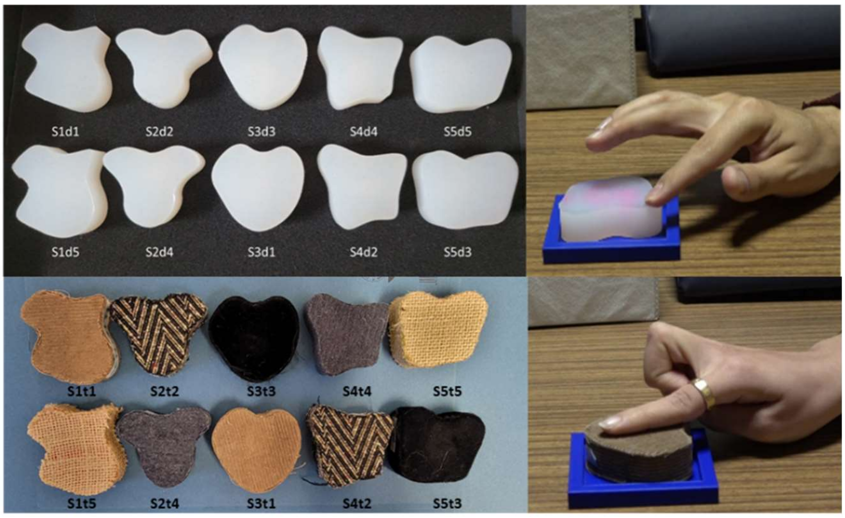


Fig. 1. Depiction of the experimental set-up, as well as the smooth-deformable shapes (top left panel) and textured-rigid shapes (bottom left panel) used in the experiment.

2.4 Design

Over two consecutive days, participants engaged in two sessions, each lasting approximately 1.5-2 hours. In one session, they made judgments on deformability or shape (using the smooth-deformable shapes –deformability/shape condition), and in the other session, they made judgments on texture or shape (using the textured-rigid shapes – texture/shape condition).

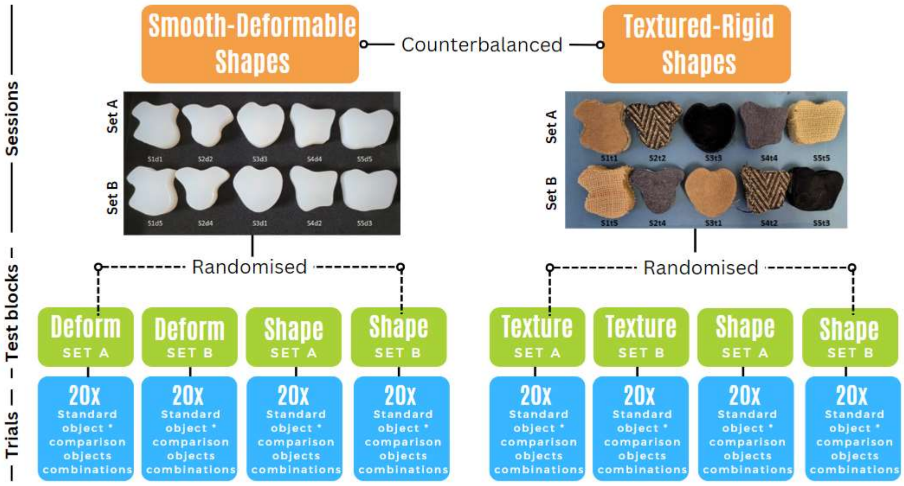
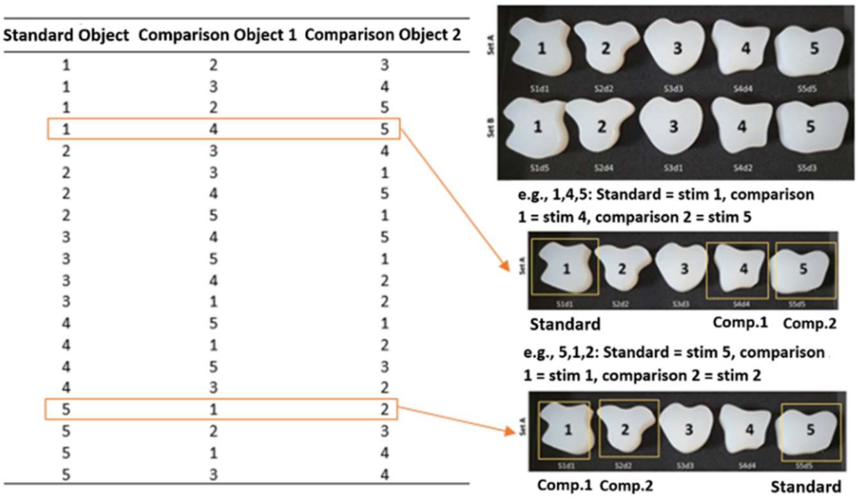


Fig. 2. The flow chart of the experimental conditions.

Within each session, participants underwent a practice block followed by four test blocks. In the practice block, participants were given ten practice trials featuring random standard object comparison object combinations. In the deformability/shape session, these four test blocks comprised two deformability blocks and two shape blocks. Conversely, in the texture/shape session, participants completed two texture blocks and two shape blocks.

Each test block exclusively utilised stimuli from either set A or B, with the order of these test blocks randomised across participants. Within each test block, participants completed 20 trials, each corresponding to a distinct standard object comparison-object combination, resulting in 80 trials completed in total for each session (See **Fig**. 2).



Standard Object	Comparison Object 1	Comparison Object 2
1	2	3
1	3	4
1	2	5
1	4	5
2	3	4
2	3	1
2	4	5
2	5	1
3	4	5
3	5	1
3	4	2
3	1	2
4	5	1
4	1	2
4	5	3
4	3	2
5	1	2
5	2	3
5	1	4
5	3	4

Fig. 3. Depiction of 20 standard object × comparison objects combinations used in the current experiment, along with an explanation of the numerical references within our list and the corresponding object in our stimuli.

Each set of stimuli (e.g., smooth-deformable set A) comprised 5 objects, allowing us to generate 20 distinct standard object comparison-object combinations. To ensure comprehensive coverage, each object served as the standard four times, while the remaining 4 objects were presented as comparison objects twice (see **Fig.** 3). In each trial, one object was designated as the standard, accompanied by two comparison objects.

2.5 Procedure

After providing their informed consent, participants were asked to sit facing the table, they were blindfolded, and we assessed the 2-point discrimination thresholds. Afterwards, they were given instructions for the experimental task. Participants were told to perform a match-to-sample task: they were presented with a standard object, and two comparison objects, which they would explore for one of the two object properties (deformability or shape; texture or shape), and their task was to select the comparison object that best matches the standard in terms of the specified dimension. It should be noted that while we have collected the data and video recordings for texture judgements, our focus in this study was mainly on the deformability and shape data of textured and deformable objects.

Each trial began with participants placing their right hand on the table, palm facing upwards, and began their exploration on the experimenter's signal. Using their right hand index finger, participants explored the stimulus at their own pace, concluding by placing their hand on the table to signal completion. Afterwards, the experimenter presented two comparison objects sequentially. Once the participant had explored all three objects, they made their judgements by saying 'first' or 'second', referring to the number of the best matching comparison objects. Participants were reminded that there is no right or wrong answer, and there would be no identical match to the standard object, and they would have to select the best matching one. Simultaneous comparison of the stimuli was not allowed, and the participants explored each object only once. Participants were not given explicit instructions on how to explore the objects to avoid biases in their explorations; they were only instructed to explore the object with a single finger. There was no time limit for exploration or response.

3 Data Analysis

3.1 Similarity Judgements

Using participants' perceptual judgments, we calculated Cronbach's alpha coefficients between participants for every standard object × comparison object combination to assess the consistency of their perceptual judgments across each dimension - deformability, smooth-deformable shape, and textured-rigid shape. Additionally, we analysed how frequently objects were rated as being most similar to a given standard object within each dimension. We did this by examining the instances in which an object was chosen as more similar when compared to another, counting the number of such occurrences, and dividing it by the total number of comparisons.

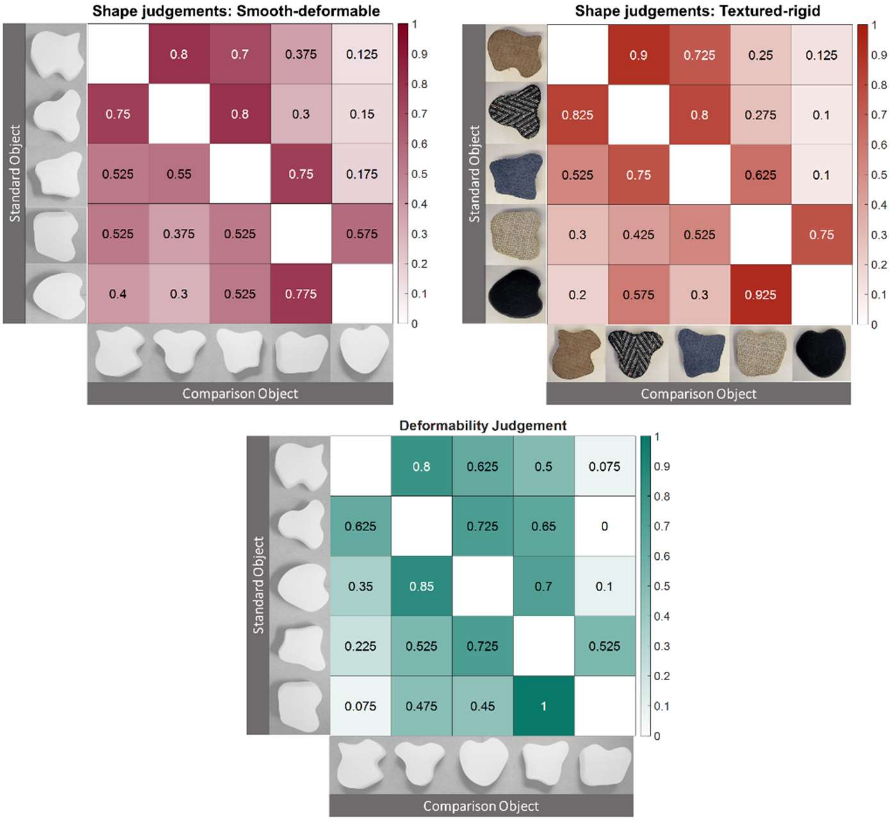
3.2 Finger Movements

We categorised participants' finger movements into nine different EPs and computed the relative frequency of the EPs. We conducted two separate MANOVAs to examine whether EP usage varied as a function of 1) the object dimension of the task (shape vs. deformability judgements) and 2) the material properties of objects (smooth-deformable shapes vs. textured-rigid shapes). Additionally, we used video recordings of finger movements to quantify the duration of exploration per trial. We compared the mean exploration time as a function of object dimension and material properties using paired t-tests.

4 Results

4.1 Similarity Judgements

In the texture/shape condition, participants made judgements about the similarity of objects based on texture and shape, whereas in the deformability/shape condition, they made judgements about the similarity of objects based on deformability or shape. The Cronbach's alpha values for smooth-deformable shape, textured-rigid shape and deformability were 0.476, 0.758 and 0.895, respectively. Deformability judgements exhibited a high level of interobserver consistency, while the interobserver consistency for textured-rigid shapes was slightly lower; it still had an overall good level of consistency. In contrast, similarity judgments on smooth-deformable shapes exhibited a



Shape judgements: Smooth-deformable

	0.8	0.7	0.375	0.125
0.75		0.8	0.3	0.15
0.525	0.55		0.75	0.175
0.525	0.375	0.525		0.575
0.4	0.3	0.525	0.775	

Shape judgements: Textured-rigid

	0.9	0.725	0.25	0.125
0.825		0.8	0.275	0.1
0.525	0.75		0.625	0.1
0.3	0.425	0.525		0.75
0.2	0.575	0.3	0.925	

Deformability Judgement

	0.8	0.625	0.5	0.075
0.625		0.725	0.65	0
0.35	0.85		0.7	0.1
0.225	0.525	0.725		0.525
0.075	0.475	0.45	1	

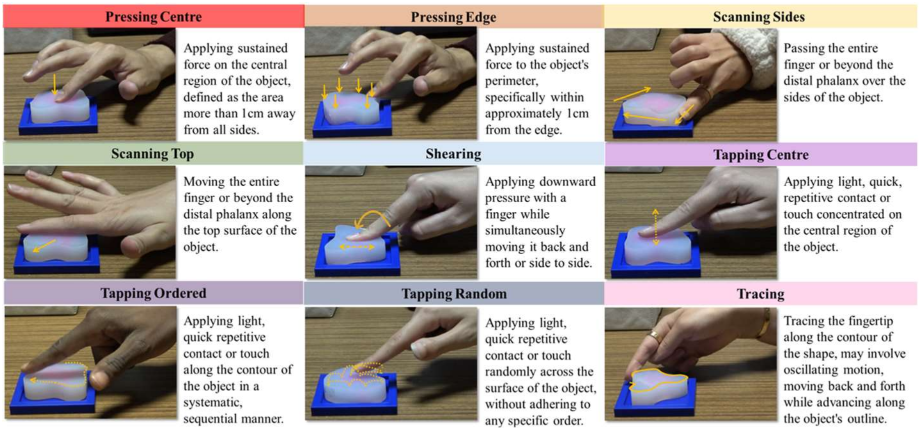
Fig. 4. Top panel: Perceived similarity in smooth-deformable (left) or textured-rigid (right) shapejudgments. Objects are arranged from those with a higher number and more prominent convexity/concavity on the left to those with fewer on the right. Bottom panel: Perceived similarity in deformability judgements, the objects are arranged from most soft to least soft, progressing from left to right. These similarity matrices illustrate how often an object was rated as most similar to a given standard object, with light colours indicating lower values and darker colours indicating higher values.

lower level of consistency, suggesting substantial variability among participants in their perceptual assessments of shape in this condition.

Next, we assessed how often an object was rated to be most similar to a given standard object by examining the instances in which an object was chosen as more similar when compared to another. In Figure 4, we show a visualisation of the perceived similarity in participants' perceptual judgements across dimensions, incorporating the perceived similarity ratings from both Set A and B. To enhance clarity, we have chosen stimuli from Set A as exemplars in our visualisation since the deformability in Sets A and B exhibit inverse variations. It should be noted that the arrangement of items in these visualisations was based on subjective judgements, except for deformability, which was based on compliance level measurements. The arrangement of shapes, determined by the number and prominence of convexity/concavity, was carried out by two of the authors (LL, K.Doerschner) and a naive participant unaware of the experiment's details. These arrangements are subjective judgments from these individuals and are solely for visualisation purposes. Furthermore, despite low interobserver consistency within the smooth-deformable shape judgement, participants demonstrated high similarity in shape judgements across material properties (smooth-deformable vs. textured-rigid). The correlation between the similarity matrices of smooth-deformable shape judgments and textured-rigid shape judgments (i.e., top left and right figure) was notably strong: r = 0.924, *p* <.001.

4.2 Finger Movements

Prior to video coding, 80 video snippets of the shape and deformability conditions were randomly selected from all participants' video recordings. The authors and two raters watched these videos together and discussed the observed events. Through discussion and further refinement, we identified nine specific finger movements that were frequently observed among participants during shape and deformability judgements. Examples of each of these EPs are shown in Figure 5.



Pressing Centre
Applying sustained force on the central region of the object, defined as the area more than 1cm away from all sides.

Pressing Edge
Applying sustained force to the object's perimeter, specifically within approximately 1cm from the edge.

Scanning Sides
Passing the entire finger or beyond the distal phalanx over the sides of the object.

Scanning Top
Moving the entire finger or beyond the distal phalanx along the top surface of the object.

Shearing
Applying downward pressure with a finger while simultaneously moving it back and forth or side to side.

Tapping Centre
Applying light, quick, repetitive contact or touch concentrated on the central region of the object.

Tapping Ordered
Applying light, quick repetitive contact or touch along the contour of the object in a systematic, sequential manner.

Tapping Random
Applying light, quick repetitive contact or touch randomly across the surface of the object, without adhering to any specific order.

Tracing
Tracing the fingertip along the contour of the shape, may involve oscillating motion, moving back and forth while advancing along the object's outline.

Fig. 5. Illustration and description of the nine EPs proposed in this experiment. Yellow arrows depict the direction and trajectories of movement.

EP coding and Relative EP frequencies. For the deformable data set (smooth-deformable shape/deformability judgements), one rater coded the entire video dataset, while an additional rater independently coded the same 50% of videos to assess interrater reliability. For textured-rigid data set (textured-rigid shape judgements), one rater coded the entire video dataset, and additional two raters coded the same 25% of videos to assess interrater reliability, and once again, interrater reliability was assessed. In general, the interrater reliability was high (Cronbach's alpha =.992-.994), suggesting that all raters have coded the videos and EP in a consistent manner.

Using the nine EPs proposed above, participants' finger movements during exploration were coded. In each trial, the occurrence of EPs was coded by annotating each EP's start and end points. Subsequently, we computed the relative frequency of EPs by dividing the duration of a specific EP by the total duration of all EPs in that trial so that the sum of relative EP frequencies for all EPs executed in each trial equals 1. The relative EP frequencies from the coding of the videos were averaged across raters, and these relative EP frequencies were used in all subsequent analyses.

4.3 EP Patterns During Smooth-Deformable And Deformability Judgements

Using these relative EP frequencies (40 trials per participant per condition), we conducted a MANOVA to investigate the effects of object properties on EP patterns, where the frequencies of the nine EP were the dependent variables and the object property (deformability/shape) was the independent variable. We found a significant effect of dimension on EP pattern, $F(9,630)$, $p <.001$, Wilk's $\Lambda = 0.013$, $\eta_p^2 = .987$, which suggests that the frequencies of EP differed depending on the object dimension of the task

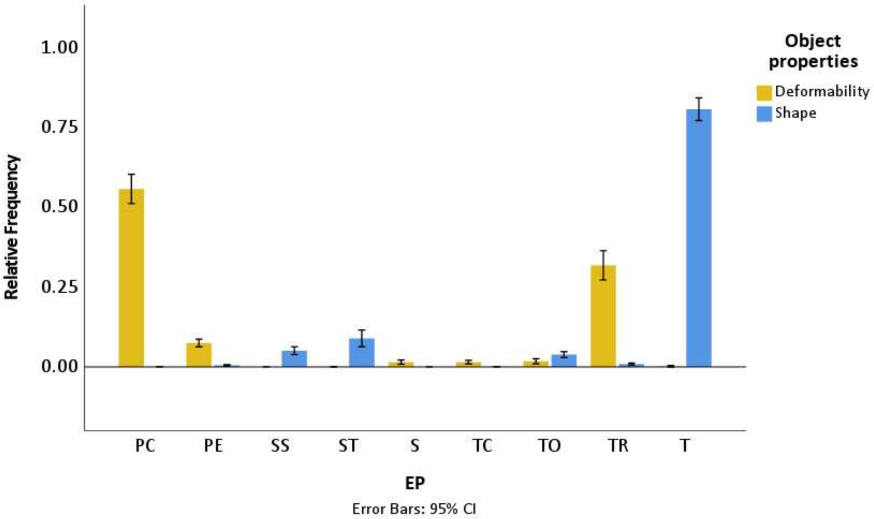


Fig. 6. Relative EP frequencies plotted as a function of object properties (deformability vs. shape). **PC** = pressing centre, **PE** = pressing edge, **SS** = scanning sides, **ST** = scanning top, **S** = shearing, **TC** = tapping centre, **TO** = tapping ordered, **TR** = tapping random, **T** = tracing.

(i.e., deformability vs shape judgements). Subsequent Univariate ANOVAs indicated that the EP frequencies differed significantly across object properties for all EPs (See **Table** 1). Overall, during shape judgments, tracing emerged as the predominant EP, followed by scanning and ordered tapping movements. Conversely, pressing and random tapping movements were the most frequently observed EPs during deformability judgments (See **Fig.** 6).

4.4 The Influence Of Material Properties On EP Patterns During Shape Judgements

We conducted a MANOVA to investigate the effects of material properties on EP patterns during shape judgements, where the frequencies of the nine EP were the dependent variables and the material property (Smooth-deformable/Textured-rigid) was the independent variable. Analysis revealed a significant effect of material properties on EP patterns, $F(7,632)$, $p < .001$, Wilk's $\Lambda = 0.910$, $\eta_p^2 = .090$, indicating that EP frequencies differed based on the material properties of stimuli. Univariate ANOVAs indicated significant differences in EP frequencies across material properties for all EPs except for Scanning sides and Tapping center (see **Table** 1). However, the EP shearing was not used during shape perception.

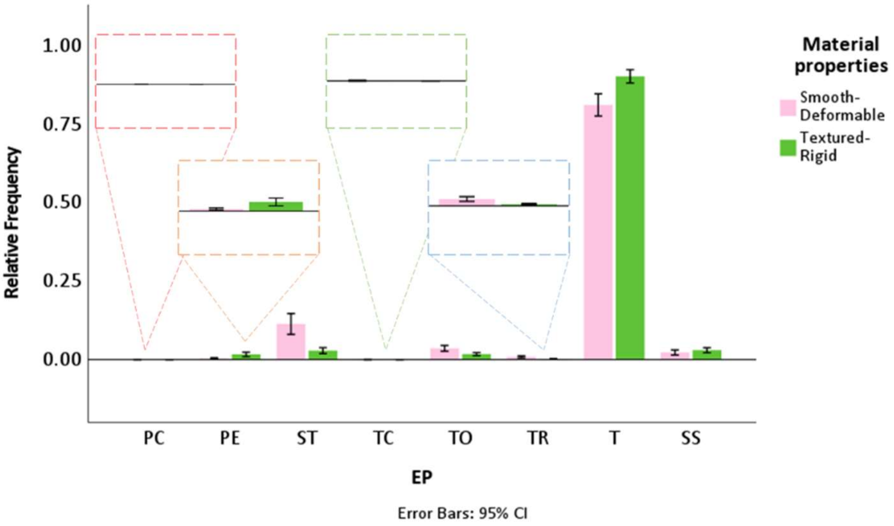


Fig. 7. Relative EP frequencies plotted as a function of material properties (smooth -deformable vs. textured-rigid). **PC** = pressing centre, **PE** = pressing edge, **SS** = scanning sides, **ST** = scanning top,**TC** = tapping centre, **TO** = tapping ordered, **TR** = tapping random, **T** = tracing. The EP shearing was omitted from the plot as it was not used.

Our results suggest that material properties have some influence on the EPs used during shape perception. Although tracing was the most commonly used exploratory procedure across smooth-deformable and textured-rigid shapes, our participants also utilised additional exploratory procedures such as scanning top and tapping ordered more often when exploring smooth-deformable shapes (see **Fig.** 7).

Table 1. Univariate analysis of variances across object properties and material properties.

Object Properties	Deformability vs. Shape judgments (Dfs: 1,638 for all dependent variables)			**Material Properties**	Textured-Rigid vs. Smooth-Deformable Shape judgements (Dfs: 1,638 for all dependent variables)		
Dependent Variable	*F* value	*p* value	η_p^2	**Dependent Variable**	*F* value	*p* value	η_p^2
Pressing centre	556.955	<.001	0.466	Pressing centre	4.802	.029	.007
Pressing edge	127.328	<.001	0.166	Pressing edge	9.822	.002	.015
Scanning sides	62.589	<.001	0.089	Scanning sides	2.413	.121	.004
Scanning top	45.037	<.001	0.066	Scanning top	20.691	<.001	.031
Shearing	17.188	<.001	0.026	Shearing	.	.	.
Tapping centre	24.931	<.001	0.038	Tapping centre	3.391	.066	.005
Tapping ordered	11.000	<.001	0.017	Tapping ordered	15.023	<.001	.023
Tapping random	176.529	<.001	0.217	Tapping random	18.435	<.001	.028
Tracing	1979.163	<.001	0.756	Tracing	21.208	<.001	.032

4.5 Exploration Time As A Function Of Object Properties And Material Properties

We investigated if participants' exploration times varied across the object object properties and material properties. Paired t-test revealed significant differences in exploration time based on object properties, with participants spending more time exploring before making shape judgments (*M* = 12.28, *SD* = 8.715) compared to deformability judgments (*M* = 3.614, *SD* = 3.342, *t*(959) = 33.847, *p* < .001). Additionally, exploration time also varied based on material properties, with participants spending more time

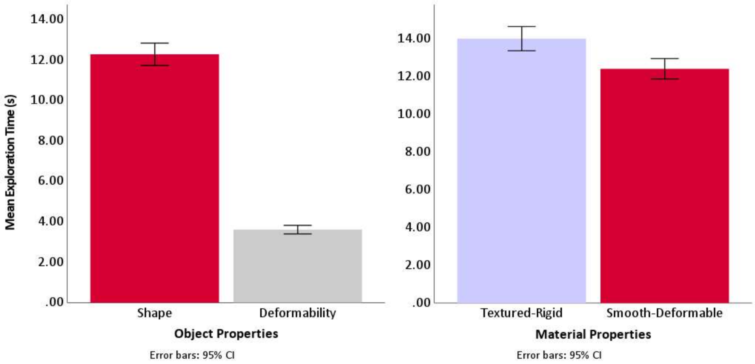


Fig. 8. The mean exploration time plotted as a function of object dimension (left) and as a function of material properties (right).

exploring textured-rigid shapes (*M* = 13.94, *SD* = 10.129) compared to smooth-deformable shapes (*M* = 12.398, *SD* = 8.556, *t*(959) = 5.498, *p* < .001), see **Fig.** 8.

5 Discussion

Previous research has demonstrated that observers are apt at identifying the most efficient EP for perceiving the target haptic properties, and they strategically adapt their movement parameters based on task or stimulus properties to optimise performance. In this experiment, we explored variations in EP usage during different tasks performed with the same set of objects varying in two dimensions in single-finger exploration. Additionally, we investigated whether EP usage differs with respect to object properties unrelated to the aim of exploration.

In line with previous studies, our results demonstrated a substantial influence of the perceptual task on the selection of EPs [1, 4-5]. When executing different perceptual tasks using the same sets of objects varying in dimensions, participants exhibited varying EP usage based on the specific task. Furthermore, we found that even under the constraint of single-finger exploration, participants consistently use task-specific EPs. For shape judgements, participants predominately used tracing, whereas, for deformability judgements, they relied on pressing to assess deformability [9-10]. These findings suggest that, in the current context, the tasks and targeted haptic properties strongly shape the use of EPs, and the effectiveness of these EPs remains relatively unaffected by the constraint of restricted single-finger exploration.

Additionally, within a given task, we observed slight variations in the use of EPs as a function of material properties. When exploring textured-rigid shapes, tracing clearly dominated the EP patterns, whereas when exploring smooth-deformable shapes, participants not only traced along the contour of the shape but also often supplemented it with additional EPs such as tapping and scanning. Although these supplementary EPs were not exclusively used for smooth-deformable shape judgments, they were more frequently observed compared to textured-rigid shape judgments. This finding aligns with existing literature, tracing emerged as the predominant EP for acquiring shape information, regardless of the number of fingers used for exploration [e.g. 1, 9]. However, given the limited participant pool in our study and the constraints of single-finger explorations, it is possible that the EPs observed and described might not encompass the full possible range of exploration patterns. Possibly, using multiple digits or whole-hand exploration may result in different patterns of results, and would provide insights into how exploration constraints impact EP usage, particularly in relation to object properties unrelated to the primary aim of exploration. This question would be very interesting to explore in the future.

Nevertheless, we speculate that the more frequent usage of additional EPs during deformable shape judgements likely served as a strategy to obtain shape information while compensating for single-finger explorations and the deformable nature of the objects. This is supported by the similarity in participants' shape judgements across conditions, even with variations in EP usage during the exploration of textured-rigid and smooth-deformable shapes. It is plausible that the observed EPs provide comparable perceptual information, thus contributing to participants' consistent shape judgements. The observed variations in EP usage suggested that individuals strategically modify their exploration strategies when encountering object properties unrelated to the primary task to enhance the acquisition of consistent and relevant information for the primary task. These findings also have potential applications in other domains, such as in the development of robotic exploration strategies. It offers potential for transferring human single-finger exploration strategies to single-digit robotic explorations across diverse contexts.

Interestingly, despite the increased use of additional EPs when exploring smooth-deformable shapes, participants spent less time exploring them overall compared to textured-rigid shapes. Hence, we wonder whether the perceived pleasantness of the stimuli, potentially influenced by factors such as the stickiness of silicone material, might have influenced exploration behaviour. It is possible that participants utilised additional EPs during the exploration of smooth-deformable shapes not only to compensate for the deformable nature of the objects but also to quickly obtain sufficient perceptual information in a shorter amount of time to avoid prolonged discomfort. Although we did not directly measure perceived pleasantness in our experiment, it raises the intriguing possibility that EP usage may also vary based on hedonistic goals unrelated to the primary haptic task.

Regarding perceptual judgements, we observed low interobserver consistency in participants' similarity judgements about smooth-deformable shapes, suggesting substantial variability among participants in their perceptual assessments of deformable shapes. This lower agreement among participants possibly stems from the challenge of forming stable shape representations due to the deformable nature of the stimuli, thus introducing more variability in their perception of shape similarity. Yet, interestingly, participants had similar shape judgements across textured-rigid and smooth-deformable conditions, implying the ability to perceive shape similarity irrespective of material properties. Plausibly, participants may have focused on certain underlying structural information, for instance, shape or geometric features, such as the magnitude of curvature of the number of convex/concave elements in their judgements. This hints at the possibility that participants may have either ignored or attenuated local tactile information unrelated to the primary task, e.g. deformability, and compensated for it by extracting shape information through other available cues such as kinematic or proprioceptive cues [e.g. 11]. Furthermore, there were no identical shapes in the current experiment, which raises the question of whether participants prioritised certain shape locations as more informative in their similarity assessment. Future research using similar stimuli can explore whether individuals exhibit a preference for certain shape locations or find certain areas more informative than others. This would allow us to identify what kind of shape cues contribute to perceiving one shape as more similar to a given reference shape than others and provide insights into factors that influence our shape similarity perception.

Taken together, the current study examined the variation in EP usage based on different tasks performed with the same set of objects varying in two dimensions, and we explored whether EP usage differs based on object properties unrelated to the aim of exploration. Our findings revealed a robust influence of perceptual tasks on the selection of EPs, even when exploration was confined to a single finger. Additionally, we demonstrated that perceivers could strategically adapt their use of EPs to obtain information pertinent to the primary task, even in the presence of additional properties that are unrelated to the primary task.

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