THE ROLE OF PRIOR KNOWLEDGE AND VISUAL CUES ON PERCEIVED SOFTNESS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

FATMA KILIÇ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF PSYCHOLOGY

FEBRUARY 2023

Approval of the thesis:

THE ROLE OF PRIOR KNOWLEDGE AND VISUAL CUES ON PERCEIVED SOFTNESS

submitted by **FATMA KILIÇ** in partial fulfillment of the requirements for the degree of **Master of Science in Psychology, the Graduate School of Social Sciences of Middle East Technical University** by,

Prof. Dr. Sadettin KİRAZCI
Dean
Graduate School of Social Sciences

Prof. Dr. Mine MISIRLISOY
Head of Department
Department of Psychology

Assist. Prof. Dr. Dicle N. DÖVENCİOĞLU
Supervisor
Department of Psychology

Examining Committee Members:

Assoc. Prof. Dr. Aslı KILIÇ ÖZHAN (Head of the Examining Committee)
Middle East Technical University
Department of Psychology

Assist. Prof. Dr. Dicle N. DÖVENCİOĞLU (Supervisor)
Middle East Technical University
Department of Psychology

Assist. Prof. Dr. Burcu Ayşen ÜRGEN
Bilkent University
Department of Psychology

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name: Fatma KILIÇ

Signature:

ABSTRACT

THE ROLE OF PRIOR KNOWLEDGE AND VISUAL CUES ON PERCEIVED SOFTNESS

KILIÇ, Fatma
M.S., The Department of Psychology
Supervisor: Assist. Prof. Dr. Dicle N. DÖVENCİOĞLU

February 2023, 148 pages

Haptic perception is the active exploration of materials by touch. When exploring objects, we use stereotypical hand movements called ‘Exploratory Procedures’ (EPs, Lederman & Klatzky, 1987). These EPs are related to the specific material and task properties, such as rubbing a jersey to assess its softness. Softness of a material has been treated as a single dimension and in fact identified with compliance (Lederman & Klatzky, 1987; Baumgartner, 2013; Di Luca, 2016). However, it has recently been shown that perceived softness is multidimensional, and people use specific EPs for perceptual softness dimensions (Dövencioğlu et al., 2022). The aim of this thesis is to understand how much prior knowledge, and visual cues account for the specific EPs associated with softness dimensions. Are the EPs based on the prior knowledge of observations and information that is learned? Or do people infer material properties from the current visual information that they obtain from the material? In Experiment 1, how much prior knowledge and visual cues affect the softness judgments in the absence of haptic sensory input was investigated. Here, it was observed that there can be material- and adjective-specific differences between prior knowledge and visual cues. Experiments 2 and 3 aimed to understand how appearance of EPs affect the softness perception of a material. It was found that a congruent EP that is correlated with the same dimension as the material yielded different ratings compared to an incongruent EP. This difference was observed partially for the adjectives that are semantically associated with the same dimension.

Keywords: softness perception, haptic perception, prior knowledge, visual cues

ÖZ

VAR OLAN BİLGİLERİN VE GÖRSEL İPUÇLARININ YUMUŞAKLIK ALGISINDAKİ ROLÜ

KILIÇ, Fatma
Yüksek Lisans, Psikoloji Bölümü
Tez Yöneticisi: Dr. Öğr. Üyesi Dicle N. DÖVENCİOĞLU

Şubat 2023, 148 sayfa

Dokunsal algı, dokunma yoluyla malzemelerin aktif olarak keşfedilmesiyle gerçekleşir. Ellerimizi, kalıplaşmış el hareketleri olan 'Keşifsel Hareketler' (KH) (Lederman ve Klatzky, 1987) kullanarak objeleri keşfetmek için kullanırız. Bu KH'ler, malzemenin doğasına ve görevin amacına göre değişir, örneğin materyal kalitesini değerlendirmek için bir kumaşı ovmak gibi. Literatürde yumuşaklık tek bir boyut olarak ele alınmıştır ve aslında esneklik ile bir tutulmuştur (Lederman ve Klatzky, 1987; Baumgartner, 2013; Di Luca, 2016). Ancak son zamanlarda, algılanan yumuşaklığın çok boyutlu olduğu ve insanların farklı boyutlar için faklı KH'ler kullandığı gösterilmiştir (Dövencioğlu et al., 2022). Mesela, bir kumun tanecikli olup olmadığını anlamak için onu ellerimizin arasından akıtırken, süngerin yumuşaklığını anlamak için ona baskı uygularız. Bu tezin amacı, yumuşaklık boyutuyla alakalı olan KH'lerin seçiminde var olan bilgilerin ve görsel ipuçlarının rolünü anlamaktır. KH'ler gözlemlenen ve öğrenilen bilgilere mi dayanıyor yoksa insanlar keşif sırasında materyalden elde ettikleri mevcut görsel bilgilerden faydalanarak mı malzeme özelliklerini anlamlandırıyorlar?

Deney 1'de, dokunsal keşif olmadığında var olan bilgilerin ve görsel ipuçlarının yumuşak malzemelerin muhakemelerini ne kadar etkilediği araştırılmıştır. Sonuçlar, var olan bilgiler ve görsel ipuçları arasında malzemeye ve sıfata özgü bir farklılık olabileceğini göstermiştir. Deney 2 ve 3, KH'lerin bir malzemenin yumuşaklık algısını nasıl etkilediğini anlamak amacıyla yürütülmüştür. Malzemelerin bağlantılı olduğu boyutla ilişkili olan uyumlu KH'lerin, uyumsuz KH'lere kıyasla farklı oylamalar açığa çıkardığı bulunmuştur. Bu fark, semantik olarak aynı boyutla ilişkili sıfatlarda kısmen gözlemlenmiştir.

Anahtar Kelimeler: yumuşaklık algısı, dokunsal algı, var olan bilgiler, görsel ipuçları

To all the strongest women in the universe

ACKNOWLEDGMENTS

I would like to start by expressing my deepest gratitude to my supervisor Assist. Prof. Nahide Dicle Dövencioğlu. Thanks to her support and help throughout the last three and a half years, I could finish this chapter of my life successfully, my master's degree. Through her guidance, I have taken a big step toward becoming a researcher. I also want to thank Assist. Prof. Burcu Ayşen Ürgen and Assoc. Prof. Aslı Kılıç Özhan for sparing their time to become jury members and sharing their valuable opinions.

I feel blessed by being surrounded by incredible lab members and I would like to thank every one of them. Melis Hazır, my cohort, was always there in my time of need and offered every help that she can. I thank her a lot for all those times that we spent together to achieve better. I also thank Ceyda Koca for supporting me and uplifting my mood whenever I needed it. Even though you have become a part of the lab recently, you were always helpful and supportive. I also want to thank all of our undergraduate students who were there for me during my presentation, either physically or by heart: Aybüke Bilir, Betül Ayça Coşar, Ebru Özden, Fatma Çelebi, Hamza Nalbantoğlu, İzel Deniz Vardar, Ömer Faruk Yıldıran, and Özce Özceçelik.

I want to offer my love and a bunch of thanks to Zeynel Yıldırım, Meryem Tunçkanat, Tuğba Hato, and Loay Akmal Mustafa Kemal Madbouly for being my fellow sufferers and embracing me with their love and support. I want to thank Tuğba Hato for being such a precious cohort whose friendship I will always cherish. I want to thank Loay Akmal Mustafa Kemal Madbouly for being my motivational speaker and late-night walk buddy. And I would like to express my love and gratitude for the two most amazing friends on earth: Zeynel Yıldırım, and Meryem Tunçkanat. Thank you for being my family and comfort zone. I am happy to be your Steve.

I thank my dear friends that METU has introduced me to: Özlem Yeter, Suzan Akkad, and Ata Nosratinia. And I also would like to thank my good friends: Fatih Karaca and Yunus Demirel. I also want to express my gratitude to my dearest friends who are always one phone call away. I must be the luckiest person in the whole wide world for having such amazing friends with the kindest hearts: my best friend forever, Merve Cürgül (Karaca), my other bestie, Beyza Şahin (Kılınç), my dearest and loveliest friends since high school, Ecem Deniz Ege (Kaya), Emine Esra Kuyumcu, Zeynep Ağar, and Ceren Temiz. These kindred spirits have always been there for me whenever I need them.

My beloved family deserves the best of all thanks: my mother, Nihal Kılıç, my father Feti Ahmet Kılıç, and my little brother, Umut Celal Kılıç. I am so lucky to have you guys to offer me a shoulder to cry on, a warm hug to feel safe, and love and understanding to follow my own path. Even though we have our differences, we have always known what the other one needs and have been ready to share our unconditional love. Thank you for being my family and the biggest support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Humans actively explore materials in the environment by touching them. The sensory system enables humans to obtain information about object features, such as shape, size, texture, and roughness. For instance, people tend to rub a jersey to get information about its fabric's roughness and/or softness or stir a liquid in order to find out its density and fluidity. Humans are able to successfully learn about material qualities, as seen from the examples, and while doing this they use distinctive hand movements related to the material property of which they want to obtain the information, such as rotating an object to explore its shape but static contact (without applying pressure) to a metal chair to measure its temperature. The stereotypic hand movements that are used to explore material properties are called 'Exploratory Procedures (EPs)' (Lederman & Klatzky, 1987). The EPs are closely linked to the specific object and task properties, for example, while haptically exploring a mug, people hold its handle to learn its function (affordance) but enclose their hand around it to explore its shape. Therefore, we can see that different EPs reveal different information about an object's properties. A study done by Atkinson et al. (2013) is in line with this view. In their study, they designed an approach to create interactive videos in which the material properties of textiles can be conveyed to viewers clearly because they stated that visual, tactile, auditory, and/or proprioceptive properties of textiles are lost in interactive materials. They benefited from the observations on how people feel, explore and handle textiles to create a method that enables textile properties to be displayed through videos similar to real life experience. They used different EPs, lighting, and pleating conditions to test these movements, with a bi-polar rating scale (e.g., rough-smooth, thick-thin, etc.); in other words, Semantic Differentiation Method (Osgood, 1952). According to the results, they reported that a corrected lighting and manipulation technique can yield much more accurate information about the materials.

EPs are crucial in extracting material-related information in haptic exploration. As I mentioned before, different hand movements (EPs) yield different information about that material. Further, people adjust these EPs according to the material property that is related to their goal. In a study done by Kaim and Drewing (2011), they examined whether people tune their exploratory hand movements to achieve relevant information about the softness of the material. In the first experiment, they looked at whether expectation concerning the softness of a material influences the exerted force on that material. In the second experiment, they tested whether the exerted force changes depending on the differences in softness (i.e., compliance). In the third experiment, they tested how exploratory forces depend on the softness sensitivity of participants. The results indicated that participants exert higher forces when they expect harder stimuli and when the compliance difference to discriminate between stimuli is smaller. Moreover, the differential sensitivity reached a maximum level only for hard stimuli whereas the exerted force did not have any impact on soft stimuli. They concluded that participants are able to deliberately adjust the exploratory force that they use to better discriminate between materials, and it depends on expectations. In addition to all these, haptic perception helps individuals to recognize objects in the absence of sight. Examples include but not limited to world renowned Turkish painter Eşref Armağan who is congenitally blind but has developed depth perception by haptic exploration. Depending on the aforementioned aspects, the importance of haptic perception in daily life should be underlined properly, because its role in life might be more complex than we ever think.

The distinction between active and passive touch is important in the scope of haptic perception (Gibson, 1962). Whereas the latter defines passive contact with materials without exploring them through cutaneous sense, the former indicates an active exploration process in which people obtain information regarding the materials' properties. Hence, active touch yields much more information about the material and is more suitable to study to comprehend the nature and functioning of haptic experiences. While sensory information is of utmost importance, the motor cortex also plays a crucial role in material perception. It enables human beings to perform exploratory behavior and to use convenient motor actions to that behavior (Goodwin & Wheat, 2008). For instance, as people stroke a fabric, they receive sensory signals from the texture. Yet, to do that action, they need neuronal signals coming from the motor cortex to move their arms, hands, and fingers over the fabric. The interplay between sensory information (i.e., the information stored in the somatosensory cortex), and the motor cortex is more complex than we ever thought. Goodwin and Wheat (2008) stated that when sensory signals are blocked by an external agent so that they cannot be received, humans become unable to perform simple behaviors to manipulate objects. Thus, the role of the motor cortex and its interaction with the somatosensory cortex cannot be ruled out in material perception.

Object perception in the brain is distributed across several material dimensions that manifest various properties, such as softness/hardness and smooth/rough (Hollins et al., 1993; Bergmann Tiest & Kappers, 2006; Balota & Coane, 2008; Okamoto et al., 2013; Kumar, 2021). In a study where they investigated the dimensionality of tactile perception of textures, Hollins et al. (1993) used 17 tactile stimuli (e.g., wood and velvet) that were rated on five scales. They reported finding three texture dimensions as a result of a Multidimensional Scaling (MDS) analysis, which were smooth-rough, hard-soft, and springiness of surface (slippery-sticky/flat-bumpy), yet they underlined the possibility for the existence of more than three dimensions. Similar to Hollins et al. (1993), Bergmann Tiest and Kappers (2006) used MDS to look at the dimensionality of materials where they measured these materials based on their compressibility (softness/hardness) and roughness. With a free sorting task and 124 materials (ranging from wood and glass to metals and felt that are encountered in daily life), they found four dimensions. In a review, Okamoto et al. (2013) concluded that there might be five possible dimensions of tactile perception: macro and fine roughness, warmness/coldness, hardness/softness, and friction (moistness/dryness, stickiness/slipperiness).

The softness of material has been treated as a single dimension and in fact identified with compliance (Lederman & Klatzky, 1987; Baumgartner, 2013; Di Luca, 2014; Drewing et al., 2017; Metzger & Drewing, 2019). Di Luca (2014) defines the softness of a material as its ability to deform under pressure and deformation can be elastic, viscous, or otherwise. Similarly, Metzger and Drewing (2019) defined softness as a subjective experience and an object's intensive property that has the ability to deform under pressure and has a physical correlate, compliance. However, it has recently been shown that perceived softness is multidimensional, and people use specific EPs for different perceptual softness dimensions (Dövencioğlu et al., 2018, 2019, 2022). In their study, Dövencioğlu et al. (2022) asked participants to haptically explore 50 everyday materials possessing different softness properties (and nondeformable and rigid objects for control materials). During the exploration process, participants rated these materials based on 31 softness-related adjectives (Semantic Differentiation Method), such as gooey, fluffy, deformable, and silky. Besides, researchers recorded the exploratory hand movements of participants for further video event coding to investigate the correlation between materials and EPs used. The results of the study revealed four dimensions corresponding to the mechanical properties of materials: compliance, viscosity, granularity, and surface softness. Further, while exploring various soft and non-soft materials people use different EPs depending on the extracted dimensions, such as applying pressure to a sponge which is considered a compliant material but running fingers through sand which is regarded as a granular material. Based on the video coding analysis, they observed eight different EPs that people use to explore materials used in the study: pressure, rubbing, rotating, stirring, running through, tapping, stroking, and pulling. Among these, it was found that pressure was significantly correlated with compliant (i.e., deformable) materials. Rotating, rubbing, and running through were observed to be correlated with granular, pulling for viscous, and stroking for surface softness materials.

However, stirring and tapping were not significantly correlated with any dimension. The authors suggest that perceived softness is beyond compliance as it encompasses these dimensions: compliance (i.e., deformability), granularity, surface softness, fluidity, and roughness. Moreover, people utilize different EPs while exploring soft materials classified in different dimensions as well as exploring various mechanical properties possessed by the materials themselves.

As the studies mentioned above have shown, the exploration of object and material properties through active touch revealed that people use stereotypical hand movements (EPs) to extract goal-related information. Also, the properties of objects and materials manifest themselves in different dimensions. Objects in studies might reveal different numbers of dimensions depending on the variety of objects. Yet, as can be seen, the dimensionality of material properties is robust. Further, EPs have been found to be correlated with certain softness dimensions. Thus, I can say that people adjust their exploratory hand movement based on the information that they want to acquire. I expect that this thesis will provide further information about whether the properties of materials that are revealed through exploration can be manipulated by using different EPs.

1.1. Top-down Processing

Perception is the brain’s ability to interpret, organize, and categorize the information gathered by the senses. Haptic information comes from the mechanoreceptors and kinesthetic/proprioceptive receptors that are located under the skin. So, by touching we receive quite amount of information about an object such as the temperature or the shape of it. When these and every other sense, such as kinesthesis and vestibular sense bring all the sensory information together, they enable people to build a mental representation of the world, objects, materials, creatures, and so on, and to build a map of connections between materials and certain properties. However, as evidenced by numerous studies perception is not only a bottom-up process that builds on the integration of varying elements of the perceptual information but also a top-down process and affected by higher-order cognitive states, such as memory, attention, and also the goal of individuals (Wolfe, 1898; Hansen et al., 2006; Balcetis & Dunning, 2010; Witzel et al., 2011; Metzger & Drewing, 2019; see Gilbert & Li, 2013, for a review as cited in Metzger & Drewing, 2019). Balcetis and Dunning (2010) proposed that individuals' desires and internal goals can lead to biased distance perception of the natural world and the results showed a positive bias toward desirable objects and a partial dependence on the desirability of the object. Thus, the findings of this study illustrated the effect of top-down processes (desire and internal goal of the observer in this study) on perceptual information. Further, Witzel et al. (2011) suggested that acquired associations and knowledge between materials and their color affect the perception of materials independent of their perceptual complexity, and whether it is two-dimensional or three-dimensional.

Understanding the actions of others is a crucial aspect of daily life, yet this process is more complex than it seems. Since people's actions are driven by their internal goals and shaped by the context (Bach & Schenke, 2017), one simple action can have many causes and goals. For example, reaching out to a glass on the counter can have many purposes. The actor might want to grasp to wash it or to move it out of the way. Individuals are capable of deriving others' intentions by observing their actions and mirror-neuron system might play a role in this process (Kilner et al., 2007a, b; Bach & Schenke, 2017; Urgen & Saygin, 2020). Nevertheless, a bottom-up process cannot account for this phenomenon (Action Observation Network) solely. Kilner et al. (2007a, b) propose that it can be explained under the scope of predictive coding account. According to their hypothesis, the brain constantly makes predictions about the observations, and top-down and bottom-up processes collaborate to form a meaningful account of these observations. The error arisen by the prediction and the observation is used as a system to update and upgrade the predictions (also see Friston, 2005, 2010; Friston et al., 2006). Thus, people might reach better conclusions as they predict others' motives and motor actions.

1.1.1. Experience and Expectation

Bayesian statistics is an extended and modified version of statistical techniques of Helmholtz (Goldstein, 2010). It suggests reasoning where prior knowledge and the data affect the decision that is made. In line with this framework, Kersten and Mamassian (2009) propose Ideal Observer Theory. It states that the ambiguities (i.e., noise) in the world might lead to unreliable decisions. Thus, Bayesian Framework strives to achieve a model which provides the optimal decision. As they stated, an ideal observer is a model that can decide optimally under the uncertainties by calculating costs and benefits (The Generative Model). Later, the model can be compared to real human beings (i.e., test observers) to rule out the countless numbers of competing mechanisms and to reach the optimal one. In brief, while bottom-up processing allows individuals to gather information from different senses and form a representation of the world in the brain, top-down processing influences bottom-up processing by recalling already stored information. Further, it helps individuals to analyze and understand the meaning of the environment and events via a process of comparing prior information with the incoming one. As these two processes work together most of the time, they enable the brain to work in a way to avoid uncertainties. Thus, it spends less energy on ambiguities and acquire more accurate results from this process, as Bayesian principles have stated (Kersten & Yuille, 2003; Kersten et al., 2004; Friston, 2005, 2010; Friston et al., 2006; Kilner et al., 2007a, b; Kveraga et al., 2007; Kersten & Mamassian, 2009; Summerfield & de Lange, 2014; Urgen & Boyacı, 2019; Urgen & Saygin, 2020). Experience and expectations have an impact on tactile memory and the process of acquiring information. Urgen and Boyacı (2019) claim that perception is affected by existing knowledge and prior information, and received information is shaped by top-down information (Tanaka et al., 2001; Abdel Rahman & Sommer, 2008; Witzel et al., 2011; Scocchia et al., 2013; Olkkonen & Allred, 2014; Metzger & Drewing, 2019; Zoeller et al., 2019; Alley et al., 2020). A literature review done by Scocchia et al. (2013) provided support for the effect of top-down processes on bottom-up processes. It revealed that stable (e.g., learning and conditioning) and transient states of individuals (e.g., motivation and attention) influence the perception of ambiguities. Research conducted by Witzel et al. (2011) also supported this view. They investigated the effects of color perception on memory. The findings revealed that the pre-existing associations that were formed between objects and their color affect the perception of those objects. Additionally, Lezkan and Drewing (2015) investigated the initial peak forces of various types of indentations applied to soft materials. The task of participants was to explore the materials freely and then discriminate which one is softer depending on their compliance. The findings revealed that the peak forces applied to the soft materials were lower when sensory (information that is acquired through haptic exploration), or predictive signals (expectations about softness/hardness of an object) indicate so, as compared to hard materials. Hence, it can be concluded that predictive and sensory signals play an essential role in softness exploration. More importantly, given together, predictive, and sensory signals yielded more force adjustments than when only sensory signals were available. Hence, we can summarize that the importance of expectation is a critical aspect of haptic exploration, and it shapes how we perceive an object and its properties.

In literature, there are studies that examined the effect of prior knowledge regarding material properties on perceived softness. The expertise in recognition of objects might be dependent upon the extensive perceptual experience of individuals with them and having deep semantic knowledge. Abdel Rahman and Sommer (2008) carried out a study focusing on the effect of prior knowledge on perception. In their study, they used 40 different tools that were used in the previous era and the functions of them are unknown to the participants, and another 20 materials that we encounter daily. The findings illustrated that extensive knowledge influences not only involuntary semantic memory but also early visual processing which is traditionally thought to be immune to these effects. Thus, extensive knowledge shapes the perception of materials. The authors came up with two different explanations for the effect of semantic knowledge on perception. On the one hand, they argued that conceptual knowledge might have a top-down effect and, therefore it provides feature analysis with activation from sensory areas. On the other hand, they assumed that semantic knowledge might be grounded in perception. Thus, semantic information might be a reconstruction of visual information stored in related brain regions. The importance of expectation, thus the effect of top-down information, on haptic exploration processes is another focus topic that we should emphasize. A study done by Yee et al. (2013) showed the importance of top-down processes in the representations of manipulated objects. In the first experiment, participants were presented with words that they had to make a judgment about whether they are concrete or abstract while engaging in a concurrent (incompatible motion – manual condition, and mental rotation – rotation condition) and no concurrent task (simply a judgment was made – control). In the second experiment, they investigated whether their hypothesized interference (it will be much more in manual condition) would also be shown in object naming. The results of the first experiment revealed that the more one has experience with an object, the more interference was observed in manual condition, but not in other conditions. The second experiment supported the findings of the first one. An incompatible manual exploration interferes with recalling the information about the same object and naming it. Therefore, this study underlined the importance of experience and exploratory procedures in material perception. Furthermore, Zoeller et al. (2019) conducted a series of experiments on the same area. They investigated the effects of implicit and explicit prior knowledge that was presented through different sensory channels on the exploratory process and whether it results in motor adaptation. In the first experiment, they presented the information via various channels (recurrent compliance -tactile-, semantic channel, and visual channel). The rationale behind comparing semantic and visual information with tactile information was that these types of information are frequently encountered in daily life. The results indicated that the initial peak force which participants applied to hard materials was stronger than the one applied to soft ones only in recurrent compliance condition. This effect was not observed for the other two conditions. Based on this experiment, they decided to convey semantic and visual information both explicitly and implicitly, because they assumed that semantic and visual information can be implicitly received and learned. The results revealed that in the implicit condition, the initial peak force was stronger for hard materials. The difference between hard and soft materials was not observed in the condition where implicit and explicit information was presented jointly. To conclude, the research has become a study that emphasizes the importance of implicit knowledge in haptic exploration. Alley et al. (2020) carried out a study in which they examined how expectation influences material properties. To this end, they created animations that either depict a familiar object or a novel one, and these objects demonstrated mechanical properties either according to the expectations of participants (e.g., wobbling of a jelly) or in a surprising way (e.g., a jelly is broken due to a fall). The findings illustrated that objects that acted in a surprising way were perceived differently from the objects acting according to the expectations, and they observed an increase in the reaction time in surprise condition. Hence, the authors presumed that top-down information affects the bottom-up information that individuals currently receive and results in an expected difference between the surprise and expectation conditions. Further, recognizing an object not only activates its optic properties but also provides strong assumptions about the mechanical properties of materials.

1.1.2. Memory

When talking about top-down processing, memory is among the first top-down influences that have an impact on our daily life. To encode and remember the information gathered by interacting with the environment, humans use mental storage that we call memory. Tactile memory is crucial in daily life. For example, a mechanic has to know what a normal engine support bracket feels like in order to detect a broken one out of sight just by touching it. Both rapidly adapting mechanoreceptors that help humans to explore micro-geometric properties of materials, such as texture, and slowly adapting mechanoreceptors with proprioceptive receptors that enable people to perceive macro-geometric material properties, such as shape, serve to gather information for haptic memory (Gallace & Spencer, 2009).

Tactile sensory memory, like visual sensory memory, is capable of retaining a certain amount of incoming information for a brief time (Bliss et al., 1966; see also Gilson & Baddeley, 1969; Sullivan & Turvey, 1972; Watkins & Watkins, 1974; Miles, 1996; Gallace & Spence, 2008). The early studies in the field, like both Gilson and Baddeley’s (1969) and Miles (1996, a replication of Gilson & Baddeley, 1969 as cited by Gallace & Spence, 2009) studies investigated the immediate recall of the location of brief tactile stimulation applied to inter-joint regions of fingers of both hands. The authors reported that at shorter retention intervals a sensory form of tactile memory is functioning, and at longer intervals, a more centralized type of memory might be operating. Further, in their series of studies, Sullivan and Turvey (1972) touched the various parts of the forearm of the participants with an apparatus and required them to show the area that was touched before, with a rod on the apparatus. By utilizing a similar method to Gilson and Baddeley (1969), they used varying retention intervals and demanded participants to either rehearse the location of the stimuli or do a summation on a paper. The findings revealed that recall accuracy decreased when the delay between the study and the test increased, thus it is an indication of a basic decay model. The forgetting rate in this study is faster than in Gilson and Baddeley (1969)'s study (Gilson and Baddeley, 969 – 45 secs; Sullivan and Turvey, 1972 – 5 secs). Miles (1996) contended that the discrepancy between the two studies can be a result of different encoding types. In Sullivan and Turvey (1972)'s study, unlike in Gilson and Baddeley (1969)'s research, participants had to encode the location of the stimuli by articulating it (verbal encoding), therefore the secondary task (articulatory suppression) preventing recall of the stimuli location could be a factor that reduced the effect of articulatory encoding. As can be seen from these studies, in the literature, there is a discrepancy about the existence of purely modality-specific tactile sensory memory (for details see Watkins & Watkins, 1974, as cited in Gallace & Spence, 2009; Manning, 1978; Millar, 1999 for an older review).

Regardless of whether haptic memory is multisensory or not, people are good at remembering haptically explored objects, familiar or unfamiliar (Murray et al., 1975; Klatzky et al., 1985; Kiphart et al., 1988; Millar & Al-Attar, 2004; Lacey & Campbell, 2006; Lacey et al., 2007).

Hutmacher and Kuhbandner (2018) investigated the long-term memory of haptic experiences and the cross-modal recognition abilities of individuals in two different experiments. In the first experiment, participants explored 168 categorically distinct everyday objects (study objects) blindfolded. They were told to remember these objects as accurately as possible for a later memory test (immediately after the study phase or after one week). In the blindfolded haptic recognition test phase, both study objects and novel objects that were similar to the study objects were presented and participants were instructed to choose previously studied objects. In the second experiment, the task was similar, yet they were not initially warned about a later memory task. The results of two studies showed that participants' ability to distinguish between the study objects and the novel objects and their performance in the encoding of haptically explored objects, even without the intention of memorization, indicate a durable and detailed long-term memory for haptic perception.

Ferreira et al. (2019) investigated the ability of older adults to recall haptically and visually explored objects after varying intervals (1-hour, 1-day, and 1-week). The authors used 12 familiar objects and gave the participants a free recall task. The study revealed no difference between the recall accuracy of the two modalities and that the haptic system is similar to the visual system.

Another study done by Pensky et al. (2008) also focused on the resemblance between those two systems. They examined the long-term memory for tactile, visual, and cross-modal information. They presented participants with 40 objects to either visually or haptically explore, and immediately after the study phase and after a week, participants took a recognition test. The findings showed that the decay in visual and tactile memory had a similar pattern, but the performance in the visual input and recognition test was higher than in the haptic input and recognition test. The worst recognition ability was for the cross-modal test.

The literature regarding the haptic memory of softness perception is somewhat scarce and newly researched. Liu and Song (2008) conducted one pilot and two follow-up studies in order to investigate the haptic memory of softness and discrimination of haptic perception of softness. They developed a device in the laboratory, which had a motor and sensors that could control a thin elastic beam; thus, they were able to change the deformability length. During the study phase, participants were able to only haptically explore the material, and they were blindfolded in order to prevent ocular cues. The authors suggested, according to the results, that the haptic memory span of humans is similar to the one found by Miller (1956) and lies between three and four items, and their ability to distinguish soft materials is better, compared to the discrimination of hard materials (Liu and Song, 2008).

Metzger and Drewing (2019) carried out four experiments in total to investigate the effect of memory on the haptic perception of softness. In all of their experiments, the task of the participants was to compare the presented stimuli (which were silicone blocks covered with pieces of different hard and soft materials) and to indicate which one felt softer with only using indentation, i.e., pressing the index finger on the surface of the object. The results showed that the memory of soft (or hard) materials which was used to cover a silicone, made the silicone feel softer (or harder) than it usually was, thus resulting in the conclusion that the prior knowledge about the softness of an object influences the perception of softness in favor of expectation.

Prior knowledge (or top-down processes) affects the perception of objects and materials, as literature shows. Previous experience with these objects might shape their momentarily perceived properties. The extent of this information and whether it differs from the sensory information is one of the scopes of this thesis. I aimed to address the difference between the information revealed by prior knowledge and by the sensory signal that is received at that moment.

1.2. Conceptual Knowledge

Semantic memory is vast storage that contains all the knowledge one has (Sperling, 1960; Tulving & Pearlstone, 1966; Tulving, 1972), and it also has many varying dimensions within (Balota & Coane, 2008; Yee et al., 2011; Yee et al., 2017; Kumar, 2021). Stored information about words involves spelling and pronunciation as well as sensory information about how they feel or look (Balota & Coane, 2008). Hence, the relationship between perception and semantic memory has drawn attention in literature. In the study conducted by Pinna and Skdilters (2010), visual illusions were used to investigate the relationship between semantics and perception. They reported that perception cannot occur without grouping, shape, and meaning, and they complement each other. Additionally, while we experience the objects around us such as a mobile phone, we have access to both momentary sensory information and the information coming from conceptual (i.e., semantic) knowledge (Yee et al., 2011). As Yee et al. (2011) mentioned, there are perceptual (e.g., shape) and abstract (e.g., function) attributes that come together from concepts about the objects and these attributes can be triggered to attain conceptual knowledge. They contended that semantic memory is constructed in a way that conceptual representations with similar perceptual and abstract features overlap. This finding can be supporting a sensory-based distributed model of semantic memory which states that if information regarding the object properties is allocated through semantic features and if these features are encoded in neural structures that are processing perceptual information coming from interactions with the objects, conceptual representations with similar perceptual features must be overlapped. Further, sensory-based distributed models should be reconstructed such that they include a mechanical mechanism to account for abstract features.

Sensorimotor modalities, the environment, and the body all contribute to playing a functional role in cognitive processing and meaning construction. Kumar (2021) also emphasized that semantic memory representations are accessed in a mechanical way during the tasks and different perceptual features of these representations may be accessed at different time points. Thus, as Yee et al. (2013) stated, semantic memory is flexible and fluid, and it can change based on the task contrary to what the traditional views contended. What is more, semantic memory is influenced by the affective and internal states of individuals, and those states can especially enrich conceptual representations that are lacking sensorimotor associations. Yee et al. (2017), similar to Kumar (2021), support the notion that semantic representations are fluid. They are structured by experience, which tells us that the context, the task, and the momentary states of individuals can affect these representations. What is more, they are multi-dimensional and distributed over various brain regions (e.g., sensory and motor regions), such as color is processed in visual sensory areas and temperature in somatosensory regions (Allport, 1985; Damasio, 1989; Barsalou, 1999). Moreover, Balota and Coane (2008) claimed that semantic representations are not amodal, yet they are grounded in the modality that they were acquired, which means that they are modality specific. Nevertheless, a complex and multimodal representation is formed with repeated exposure to perceptual information. In addition to these, Patterson et al. (2007) reviewed “the representations of conceptual knowledge (semantic memory) in the brain”. They emphasized the multimodal nature of semantic knowledge, because if it was unimodal, then it would not be possible to categorize and generalize semantic knowledge in higher-order areas.

A study conducted by Ballesteros and Reales (2004) investigated implicit memory in healthy individuals and patients with Alzheimer's disease. In the experiment, participants haptically explored 20 objects and formed a sentence with the name of the object. After a 5-min break, they performed two tasks, one is speeded object naming test (implicit), and the other is an explicit recognition test. The task of the participants in the first test is to name the objects which are either previously studied or novel, and in the latter, the task is to report whether the object is old or new. They reported that the performance of the participants in all groups did not differ in the implicit memory task. As stated by Gallace &

Spence (2009), the result of the study might imply that the information about haptically explored objects that are stored in the brain can be verbal or visual in nature, rather than haptic. However, Easton et al. (1997) carried out a series of experiments in order to investigate how information is stored in the brain. Participants were presented with words haptically (as raised line drawings on cards) and verbally, and in the test phase, they were instructed to complete three-letter word stems with the first word coming to their minds. As a result, they argue that the identification of letters and words might be mediated between visual and haptic perception either jointly or independently. Yet, they did not find conclusive results suggesting joint representations.

In the study done by Gauthier et al. (2003), it was stated that nonvisual knowledge (e.g., semantic knowledge) interacts with visual knowledge to enable individuals to better discriminate objects (or interferes with the discrimination process). They contended that there are two types of conceptual influences on visual perception. The first one is the effects of category learning on perception in which objects learned in the same category are discriminated more slowly. The second one is the association of specific semantic features with objects which states that the association of dissimilar semantic information with objects facilitates discrimination. To study whether semantic knowledge influences perceptual judgments independent of object naming, they carried out a series of experiments. The results were in line with the hypothesis. Novel objects that were categorized in different concepts depicted a better performance in perceptual judgment task relative to the ones in similar categories. However, this influence was not observed when the categories were solely a name, or the objects were 2-D rather than 3-D. Therefore, they proposed that semantic knowledge affects perceptual judgments even in the absence of nonvisual processes.

As the abovementioned studies showed, semantic information can be stored in the brain both visually and haptically, and it can affect perceptual judgments. Thus, it can also give information about the material properties, yet to what extent is not certain. I am expecting that this thesis will yield at least a partially answer to the extent of information revealed by conceptual knowledge or contribute to literature.

1.3. Why Study the Role of Prior Knowledge on Haptic Perception Visually?

As the abovementioned studies suggest, the nature of the haptic information stored in the brain regarding whether it is multisensory or not has not reached a consensus (Aleman et al., 2001; Gallace & Spence, 2009). Lacey et al. (2007) scanned the literature to investigate the nature of haptic and visual representations and their cross-modal interactions. According to neuroimaging studies in the literature, these representations can be multimodal or unimodal. Their conclusion was in favor of multimodal representation which is spatial in nature and can be accessible from both bottom-up and top-down processes. Nevertheless, we still cannot dismiss the existence of unimodal representation altogether. The mental imagery studies done with congenitally blind and sighted individuals showed that haptic perception uses mental imagery (Gallace & Spence, 2009). As Paivio (1986, as cited by Gallace, 2009) claimed, the recall of tactile information benefits from mental images. Zhou and Fuster (1997) studied a monkey's associative cortex in a cross-modal visuo-haptic task and found that parts of the somatosensory cortex are active during the presentation of a visual stimulus that is behaviorally linked to tactile information. Thus, they concluded that those neurons in the somatosensory cortex, which is normally responsible for tactile information, may be a part of a cross-modal neural memory network. Picard (2006) investigated the relationship between vision and touch for texture and shape information. By adjusting the similarity of objects and using a cross-modal matching task, he concluded that the information gathered by only vision or only touch results in a similar percept, and the information about the texture of an object can be transferred from one modality to the other.

Okamoto et al. (2013) reviewed the articles about the psychophysical properties of tactile perception of texture and concluded that visual and haptic perception share common dimensions related to the material properties (see Yoshida, 1968 as cited in Okamoto et al., 2013). Similarly, in their comparison of vision and touch, Baumgartner et al. (2013) found that two systems are able to retrieve similar information about various material properties such as glossiness, elasticity, and texture, and might have similar underlying mental networks. Therefore, from the results of these experiments, studying tactile memory visually facilitates similar mental representation to studying it haptically and, will reveal the level of equivalence of perceptual retrieval of soft materials between vision and touch.

In another study carried out by Norman et al. (2004), they investigated the abilities of individuals to compare 3-D objects by vision and touch. In a series of studies where they used bell peppers as stimuli and manipulated the time to acquire the necessary information about the stimulus (varying from 3 to 15 secs). They reported a slight effect of experience and that there was confusion at first for the stimuli with global similarity, but if two stimuli have local differences, the ability of participants to distinguish between the two improved. Overall, the results demonstrated that there might be differences in 3-D representations of objects between touch and vision, yet it is important to emphasize that they can functionally overlap. In their study, Bergmann Tiest & Kappers (2007) investigated the haptic and visual perception of roughness. Their research questions were focused on the correlations between physical and perceived roughness, and the comparison between visually and haptically perceived roughness. 96 materials were used as stimuli and 12 participants took place in the study where their task was to order these stimuli according to their perceived softness. The findings illustrated that the perceived roughness was similar for visual and haptic senses, and the performance on a modality was dependent on how roughness was measured for comparison. The haptic condition yielded slightly better performances that were closer to the physical roughness than in the visual condition. Further, they assumed that there is no one simple description for perceived roughness that correlates with physical roughness.

Thus, it can be concluded that perceived roughness is subjective, and every individual uses different criteria to assess it.

While assessing the tactile properties of materials from photographs and videos, there are cross-modal representations in play. Yet, the accuracy of this information compared to each other is unknown. There are studies in literature that tackle this question. Wijntjes et al. (2019) investigated whether fabrics in still images and videos convey similar information to when they are seen or touched. In the first experiment, they presented participants with jeans as stimuli haptically and required them to make a visual matching task (match-to-sample task). In line with their hypothesis, they observed that videos reveal more information about material properties than photos (Wendt et al., 2010; Doerschner et al., 2011 – these two studies confirmed the hypothesis before). To further support their hypothesis, they used a visual similarity task in which participants evaluated how visually presented (videos and photos were two different conditions) materials felt (similarity judgment task). The findings demonstrated no support for the hypothesis. Rather, it revealed that visual judgments from videos or photos do not have any correspondence to haptic judgments. In the third experiment, they replicated Experiment 2 with a few alterations. In this experiment, instead of using videos and photos, they seated two participants across and while one was exploring the material by touch, the other one was only an observer of this process. Later, they both evaluated how the materials felt: whether they were similarly felt or not (similarity judgment task as in Experiment 2). Here, the authors observed a significant difference between the two groups of participants. Hence, they reported that if the videos were much closer to reality, they would facilitate much better performance in haptic judgments. Similar to this study, Cavdan et al. (2021) investigated whether haptic and visual information would yield similar perceptual spaces, in other words, whether material properties might be assessed similarly by haptic and visual evaluations or not. To this end, the authors designed three experimental conditions: haptic, static visual (photographs of materials), and dynamic visual (videos of materials). They used 19 materials and 15 adjectives, and the task of the participants was to rate the materials based on these 15 adjectives while haptically or visually exploring them. The findings of the study revealed that they observed three dimensions in static visual condition: surface softness/deformability, granularity, and viscosity. In the dynamic visual condition, the observed dimensions were four: surface softness, granularity, viscosity, and deformability. The haptic condition was observed to manifest four conditions that were found in mechanical visual condition as well as an additional one: roughness. Later on, they conducted a combined PCA on three conditions and found four dimensions: surface softness, granularity, viscosity, and roughness. Next, the correlation analysis between three perceptual spaces was analyzed. They reported that the three conditions have a significantly high correlation. The correlation between dynamic and static visual spaces was larger than between static visual and haptic spaces. Yet, it was not larger than between dynamic visual and haptic spaces. Furthermore, the correlation between dynamic-haptic was significantly larger than between static-haptic spaces. As the authors suggested, this might be a result of representational differences between the perceptual spaces. Haptic space was observed to be more differentiated as compared to two other visual spaces. Among these two, the correspondence between dynamic visual space and haptic space was better, thus revealing similar information regarding the material properties of haptic perception. Nevertheless, it is noteworthy to emphasize that these differences between perceptual spaces might be an effect of material-adjective combinations. Moreover, Xiao et al. (2016) investigated which kind of visual cues are essential for tactile judgments. As stimuli, they used fabrics, and participants were asked to visually match them according to how they felt. The goal of the experiment was to unveil the image properties contributing to tactile perception. It was observed that both color and folding shape in RGB conditions influenced tactile perceptual judgments by the information received by still images. This study is in contradiction with Wijntjes et al. (2019) because it states that still images yield accurate judgments when visually perceived. Nevertheless, as Bouman et al. (2013) stated, even though image cues can communicate a lot about material properties, they can be misleading and mechanical cues in a video can establish a firm evaluation by resolving the ambiguity. Therefore, whether the photographs and videos convey information with the same accuracy is still ambiguous, we can conclude from literature that they both reveal information about material properties and this information is similar to the information received momentarily from haptic modality.

As can be seen from literature, material properties can be conveyed through different channels. These sensory channels might have different degrees in revealing the material properties. This difference can alter the perceived properties and, in return, the perception of individuals. Thus, it is important to understand whether the information regarding the material properties extracted by videos and photographs will differ. To this end, the first part of this thesis will focus on investigating the difference between acquired information about material properties through prior knowledge, static visual, and mechanical visual cues.

Finally, in the scope of this thesis, I will use optic and mechanical properties of materials in a specific way. The optic cues of a material show how it appears on a static image, such as its glossiness, translucency and so on. The optical properties mostly depend on the interaction of the surface of a material with light (Schmid & Doerschner, 2018). The mechanical cues, on the other hand, tell observers how a material would behave under force. For instance, when you squeeze a stress ball, it will deform or when you stir hand cream, it will move along with your hand motion. Shape and motion information play a crucial role in the mechanical properties of materials (Schmid & Doerschner, 2018). Two materials can have the same optic cues but manifest different mechanical cues or vice versa. It is also important to underline that these properties might interact with one another to provide information about materials (Schmid & Doerschner, 2018).

1.4. Aims and Hypotheses

In the thesis, the role prior knowledge, and mechanical and visual cues on perceived softness has been investigated. To do this, a set of everyday materials were chosen as stimuli, and an adjective list that was created by Dövencioğlu et al. (2018, 2019) from a comprehensive set of 262 adjectives (Guest et al., 2011) was benefited. The aim of Dövencioğlu et al. (2018, 2019) was to create a list of adjectives to study softness perception, and they ended up with 31 adjectives that are descriptive of different softness dimensions. Therefore, this list suited the best to the aim and hypothesis of this thesis.

Here, in Experiment 1, the aim was to investigate how people perceive the properties of various soft materials (and rough as a control condition). The main research question was whether people make their judgments based on prior knowledge and experience with these materials, or if they benefit from momentary sensory signals (i.e., mechanical, and static visual cues). The hypotheses of Experiment 1 are as follows: (1) mechanical visual cues will provide additional information about the material properties, and (2) the benefit of mechanical visual cues will manifest itself in the ratings for the mechanical adjectives and the adjectives related to a congruent softness dimension with the material (e.g., sponge and compliant in deformability dimension).

In line with the abovementioned literature, the expected results are as follows: (1) The multiple dimensions retrieved from the materials and the adjectives here will be parallel with literature. Thus, there will be four dimensions: Deformability, Fluidity, Granularity, and Surface softness (Cavdan et al., 2021; Dövencioğlu et al. 2022). (2) Participants ratings in mechanical visual cue condition will be higher than the other two conditions (prior knowledge and optic visual cues) for the adjectives and materials that will be matched based on softness dimensions. This expected result was derived from the studies of Bouman et al. (2013) and Cavdan et al. (2021). (3) The mechanical adjectives (e.g., gelatinous, slimy, and malleable) are expected to receive higher ratings in the mechanical visual cue condition compared to the other two conditions because mechanical properties can be observed and judged better when they are shown through a video.

In Experiments 2 and 3, the main hypothesis is that the manipulation technique (i.e., Exploratory Procedures, EPs) that will be used to interact with the materials will reveal different information about the material properties and affect the judgments. Therefore, in line with the study of Dövencioğlu et al. (2022), it is expected that (1) a congruent EP that is correlated with a softness dimension will result in higher ratings than an incongruent one. Also, (2) this rating difference will be observed for the adjectives and materials which are chosen from the same dimension with the congruent EP.

CHAPTER 2

EXPERIMENT 1

2.1. Introduction

Previous studies revealed that prior knowledge influences how we perceive material properties (Abdel Rahman & Sommer, 2008; Witzel et al., 2011; Metzger & Drewing, 2019; Alley et al., 2020). Having an experience with a specific material shapes the way we attribute certain qualities to it, such as one may perceive a material as harder when it is covered with rough surface (Metzger & Drewing, 2019). A recent study carried out by Cavdan et al. (2021) investigated the perceptual correspondence of haptic, visual, and mechanical conditions in which materials were presented. Overall, they concluded that these perceptual spaces correlate well with each other. Yet, authors claimed that the differences might have yielded from the absence of prior experience related to the specific material properties or when there is an ambiguity in the material property under the investigation. Here, building on the literature we investigated the effect of prior knowledge, mechanical and optic cues on the perceived softness. Our main research questions were: When judging softness without haptic stimuli, how much of the information comes from memory? How do mechanical cues help individuals to judge material properties? Do they have certain advantages over prior knowledge and optic cues?

In the study, participants were presented with either name, photographs, or videos of everyday materials on a computer screen. By using the Likert scale ranging from 1 (not at all) to 7 (very), we collected ratings of these materials based on softness related adjectives. The aim was to compare three conditions (word, photo, and video) to find out if there are any advantages of mechanical cues (video condition) over prior knowledge (word condition) and optic cues (photo condition). This is the first hypothesis that we investigated, and we expected mechanical cues to carry additional information about material properties. Specifically, we hypothesized that the ratings of adjectives linked with mechanical properties of materials, such as elastic, gelatinous, slimy, etc., in video condition would have significantly differed from word and photo conditions.

Next, we aimed to test whether the ratings of mechanical adjectives in the video condition would be different from the other two conditions based on dimensionality. To achieve this, after individually examining the materials, we planned to conduct a second analysis with materials loaded on four dimensions determined by Principal Component Analysis. We hypothesized that (1) the mechanical adjectives would have significantly different ratings in video condition compared to the other two conditions, and (2) there would be dimension-specific differences in the ratings of adjectives between video condition and word, and photo conditions, such as in 'Granularity' dimension, we expected the adjective ‘Scaly’ to yield a significantly different rating in video condition compared to photo or word condition. The reason is that the property of a material being scaly can be seen clearly from an interactive video because we assume that the mechanical cues might be more descriptive of such properties.

2.2. Pilot Study

Before conducting Experiment 1, an online pilot study was carried out in Qualtrics.

2.2.1. Participants

45 participants (41 females, M_{age} = 24.31) participated in the study. Participants were undergraduate or graduate students from Middle East Technical University who were compensated by course credit. Participants did not report any psychological or neurological problem and they had normal or corrected-to-normal vision. Before the experiment, they were presented with a written

informed consent form on the screen and informed that they can stop the experiment at any point without a reason.

2.2.2. Stimuli and Procedure

The study was conducted online by using Qualtrics. On the top of the screen, the task was given to the participants ("İsmi yazan materyali, aşağıdaki sıfatların ne kadar tanımladığını 1 ile 7 arasında oylayınız."). Under the task, either the name, photograph or video of a material was displayed, and the adjectives were lined underneath one by one. An example screenshot from Qualtrics can be seen in Appendix C. Table 2.1 lists the adjectives that were used in the study. Initially, there were 29 adjectives that were taken from Dövencioğlu et al. (2018, 2019). This adjective list was created for the purpose of studying softness perception. Therefore, in this study and further studies, I benefitted from this list.

Table 2.1. List of 29 adjectives with their meanings in English

	Adjective (TR)	**Adjective (ENG)**		**Adjective (TR)**	**Adjective (ENG)**
1	*biçimlenebilir*	malleable	16	*odunsu*	woody
2	*dokulu*	textured	17	*parlak*	glossy
3	*esnek*	flexible	18	*pul pul*	scaly
4	*esnemez*	inflexible	19	*pürüzlü*	roughened
5	*güç uygulanabilir*	compliant	20	*sert*	hard/firm
6	*hamursu*	doughy	21	*sümüksü*	slimy
7	*hassas*	delicate	22	*süngerimsi*	spongy
8	*ipeksi*	silky	23	*tanecikli*	granular
9	*jölemsi*	gelatinous	24	*havadar*	airy
10	*kabarık*	fluffy	25	*toz gibi*	powdery
11	*kabuklu*	scabby	26	*tüylü*	hairy
12	*kadifemsi*	velvety	27	*cıvık*	gooey/sludgy
13	*kaygan*	slippery	28	*yapışkan*	sticky
14	*kum gibi*	sandy	29	*yumuşak*	soft
15	*nemli*	moisturous			

Similarly, materials were chosen among the ones used by Dövencioğlu et al. (2018, 2019). Figure 2.1 depicts the actual footage of materials that were used in the study.

Figure 2.1. The Photographs of materials that were used in the study.

2.2.3. Results

To analyze the data, we first calculated Cronbach's alpha values of the adjectives to see if the participants were consisted in their understanding of the concepts of the adjectives (See Appendix C for the results). Later, we carried out a Principal Component Analysis. PCA is an analysis that is used to reduce large datasets into a smaller number of dimensions and while doing that, try to ensure that it represents as much information as possible. To do that, first, the continuous data points were standardized. Then, every value of variables was subtracted by the mean and divided by the standard deviation. The covariance matrix was computed so that we can see how the data points varied from the mean relative to each other. Next, eigenvectors and eigenvalues were calculated from the covariance matrix. Eigenvectors account for the principal components extracted from the dataset and are the linear vectors that explain most of the information from the data. Eigenvalues, thus, are the coefficients of eigenvectors and from highest to lowest, they represent the principal components. Then, it is important to decide which component is of utmost significance and reveal information more about the dataset and which ones will be discarded. In line with the literature, I observed that there were four softness dimensions for each condition separately: Deformability, Fluidity, Granularity and Surface Softness (Cavdan et al., 2019, 2021; Dövencioğlu et al., 2018, 2019, 2022).

Next, we carried out a 3 (Condition) x 40 (Material) x 29 (Adjective) mixed ANOVA in which "Condition" is between-subject and "Material and Adjective" is within-subject design. The results showed that the difference between photo-word (*MD* = .096, *SE* = .014) and photo-video (*MD* = .079, *SE* = .013) conditions were statistically significant. However, the difference between video-word condition was not significant (*MD* = .017, *SE* = .014). Figure 2.2 demonstrates the pair-wise comparison results.

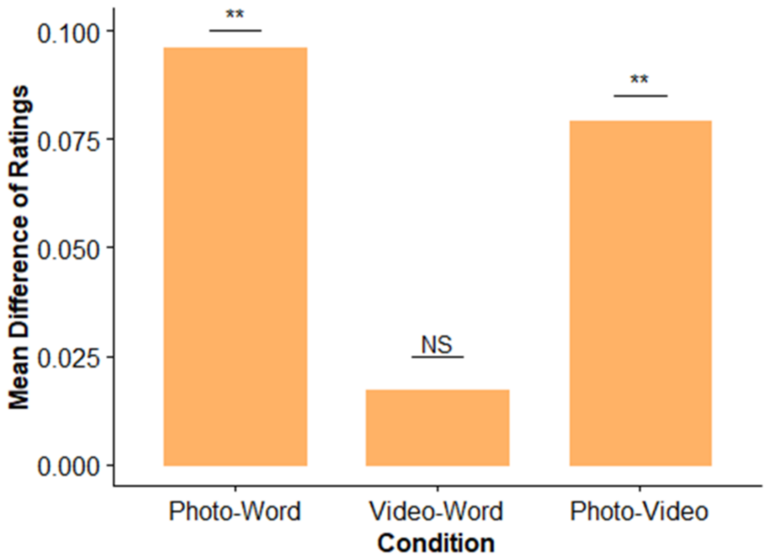


Figure 2.2. Mean difference of ratings between the conditions. The y-axis depicts the mean rating differences, and the x-axis illustrates the pair-wise comparisons of conditions.

2.2.4. Discussion

The results of the online pilot study revealed that there were four softness dimensions. As shown by Cavdan et al. (2019, 2021) and Dövencioğlu et al. (2018, 2019, 2022), this result is in line with the previous research. Yet, as Cronbach's alpha values indicated that inter-subject agreement was slightly better for photographs of the materials. What is more, we observed that there is a pattern between the conditions for fluid materials which was that mechanical visual cues have an advantage over static visual cues and prior knowledge.

Surprisingly, the difference between video and word conditions was not significant. We assumed that this unanticipated result might be due to the experimental setup. The study was carried out online, and we could not ensure that participants watched the videos and based their judgments on what they saw on the screen. Therefore, it is possible that they just saw the material on the screen and without watching the video further, they rated the materials based on prior knowledge. Moreover, the significant difference between photo and video conditions might support our assumption. If participants judge the materials based on their photos on the first frame, then we would not observe a significant difference between these two conditions. Hence, we can assume that their judgment in video condition might derive from prior knowledge.

After we conducted an online study in Qualtrics due to pandemic conditions, we later carried out the experiment in a laboratory setting with a similar design. On the next section, I will explain the details of Experiment 1 and discuss its results in light of the online pilot study.

2.3. Experiment 1

2.3.1. Method

2.3.1.1. Participants

Ninety naive participants (55 females, M_{age} = 22.82) participated in the study. The participants were undergraduate and graduate students from Middle East Technical University who received course credit for their participation or who participated voluntarily. Before starting the experiment, participants received an informed consent form, which stated the aim of the study and ensured the privacy of the participants' responses, and they were informed that they could stop the experiment at any point without reason. The study was approved by the Human Studies Ethical Committee of Middle East Technical University. Participants did not report any psychological or neurological disorder, and all had a normal or corrected-to-normal vision. The native language of the participants was Turkish. The age range to participate in the experiment was 18-35. The experiment lasted approximately 45 minutes.

2.3.1.2. Experimental Setup

The experiment was carried out on the software MATLAB R2021a using Psychtoolbox-3. The study was conducted in a laboratory setting. Participants sat in front of a computer and gave responses using the mouse. The distance of participants from the computer screen was set the same for all (60 cm). The lighting of the room was provided by a ceiling lamp; thus, it was kept the same for all participants. After the experimenter explained the instructions to the participants, she left the room, and the participant continued the study alone in a soundproof room.

2.3.1.3. Stimuli

The stimuli used in the study were the names, the photographs, and the videos of everyday materials. There were 25 materials in total ranging from fluid materials, such as shampoo, to rough ones, such as wood balls. They were chosen to be as diverse as possible to include a vast number of materials; hence, to be able to represent as many different everyday materials as possible.

The photographs and the videos were taken by the researcher in a laboratory setting. The room was illuminated by both natural light through a window and fluorescent light above. The camera which was used to capture the materials' photographs and videos was Canon EOS M50 and the distance of camera was fixed by a tripod. The ISO setting was automatic throughout the shooting process. The photographs were captured from above (the angle of the camera was 90^{o}) and the size of the photographs was 6000 x 4000 pixels. The shutter was set to either 1/125 sec. (for most), 1/60 sec. or 1/20 sec. (only for one photo) and the aperture was either f/5, f/5.6 (for most), f/6.3, f/8, or f/9 for the photographs. In the photographs, materials are placed in a square container in order to provide a consistent picture throughout all material dimensions.

The videos were taken from the frontal view. They were shot at 50 frames per second with Full HD and the size of the video files each was 1920 x 1080 pixels. To reduce the size of the video files, the size was scaled down to 1280 x 720 pixels and the quality was kept as HD.

In the videos, the hand of the researcher interacts with the material and applies Exploratory Procedures to the material, such as rubbing, stroking, and rotating it. Exploratory Procedures were chosen dependent upon the previous research (Cavdan et al., 2019; Dövencioğlu et al., 2022) which revealed that certain hand movements are related to the specific material properties. For instance, to understand how viscous hand cream is, people usually stir it, or to get information about the surface softness of a furry textile, individuals stroke its surface or rub it between their fingers. See Figure 2.3 for the material photos that were used in the experiment.

Figure 2.3. Photographs of materials in the study

2.3.1.4. Experimental Procedure

In the study, there were three different experimental conditions. They were decided in accordance with the stimulus type: the verbal condition in which the names of the materials were presented to the participants, the static visual condition in which the photographs were displayed, and the mechanical visual conditions which is the condition where the videos of the materials were presented.

At the center of the screen either the names, the photographs, or the videos of the materials were displayed. The names and the photographs of the materials stayed on the screen and the videos looped in every 5 seconds until the participants gave their responses. At the top, there was a question including an adjective in it (e.g., Bu malzeme ne kadar “biçimlenebilir”?) and the order of the materials was randomized to avoid participants adapting to the procedure. The order of both materials and adjectives was randomized for every participant. Further, it was ensured that participants answered the question for the material on the screen before proceeding to the next material and/or question.

The task of the participants was to rate either the names, the photographs, or the videos of the materials according to how much they think that the material is defined by 23 softness-related adjectives (e.g., Bu materyal ne kadar kabarık?). Table 2.2 shows the list of adjectives. We used a Likert scale ranging between 1 and 7, in which 1 means that the adjective does not describe the material at all and 7 means that the material is entirely related to the adjective.

Table 2.2. List of adjectives used in the questions

Malleable - Biçimlenebilir	Elastic - Esnek	Rigid - Esnemez
Compliant–Güç uygulanabilir	Delicate - Hassas	Silky - İpeksi
Gelatinous - Jölemsi	Velvety - Kadifemsi	Slippery - Kaygan
Sandy – Kum gibi	Moisturous - Nemli	Glossy - Parlak
Scaly – Pul pul	Roughened - Pürüzlü	Hard - Sert
Slimy - Sümüksü	Spongy - Süngerimsi	Granular - Tanecikli
Powdery – Toz gibi	Hairy - Tüylü	Gooey – Vıcık vıcık
Sticky - Yapışkan	Soft - Yumuşak	

2.3.2. Results

2.3.2.1. Analysis Plan

We first looked at the correlations between participants in each condition and created a correlation heat map, and the consistency of participants for each adjective to see whether the concepts of adjectives were clearly understood by them. Secondly, we carried out 6 separate Principal Component Analyses (PCA) to see the hidden dimensionality within adjectives and materials grouped by condition. PCA is an analysis that is used to reduce large datasets into a smaller number of dimensions and while doing that, try to ensure that it represents as much information as possible. To do that, first, the continuous data points were standardized. To do this, every value of variables was subtracted by the mean and divided by the standard deviation. The covariance matrix was computed so that we can see how the data points varied from the mean relative to each other. Next, eigenvectors and eigenvalues were calculated from the covariance matrix. Eigenvectors account for the principal components extracted from the dataset and are the linear vectors that explain most of the information from the data. Eigenvalues, thus, are the coefficients of eigenvectors and from highest to lowest, they represent the principal components. Then, it is important to decide which component is of utmost significance and reveal information more about the dataset and which ones will be discarded. After this step, the data is reoriented along new principal axes. Later, a 3 (*Condition: Photo, Video, Word*) x 23 (*Adjective: Biçimlenebilir, Esnek, Esnemez, Güç uygulanabilir, Hassas, İpeksi, Jölemsi, Kadifemsi, Kaygan, Kum gibi, Nemli, Parlak, Pul pul, Pürüzlü, Sert, Sümüksü, Süngerimsi, Tanecikli, Toz gibi, Tüylü, Vıcık vıcık, Yapışkan, Yumuşak*) x 25 (*Material: Honey, Scourer, Glass balls, Shower gel, Hand cream, Lady's Stocking, Velvet, Black pepper, Mechanical sand, Sand, Fur, Latex gloves, Microfiber cloth, Rubber band, Cotton, Hair conditioner, Sponge, Shampoo, Sugar, Wood balls, Stone, Tennis balls, Flour, Wool, Sandpaper*) mixed design ANOVA was conducted in R Studio. The results of ANOVA applied to raw data and PCA can be found in appendix. After that, since the

Bartlett test of sphericity, which shows us whether the variables are correlated or not (i.e., whether the correlation matrix is orthogonal to the identity matrix or not), in each condition is significant and materials loaded on the dimension similarly across conditions, we carried out a combined PCA with Bartlett scores. Further, after we replaced the variable "Material" with "Dimension" based on the combined PCA results, we conducted a second mixed design ANOVA (3 x 23 x 4 -dimension-) to see if the mechanical cues, optic cues, and/or prior knowledge has different depictions in different conditions.

2.3.2.2. Correlation Matrices and Consistency Analysis

Firstly, we calculated Cronbach's alpha values separately for each adjective and the values revealed that participants were highly consistent in their ratings for all 23 adjectives. The mean values for each adjective can be seen from Figure 2.4.

The cut-off for acceptable Cronbach's alpha value is between 0.7 and 0.8. The values between 0.8 and 0.9 are considered good, and when they are higher than 0.9, they are considered excellent. Overall, Cronbach's alpha values were good. Thus, we can conclude that the internal consistency of adjectives was highly reliable, and they evoked similar representations for the participants (Gliem & Gliem, 2003).

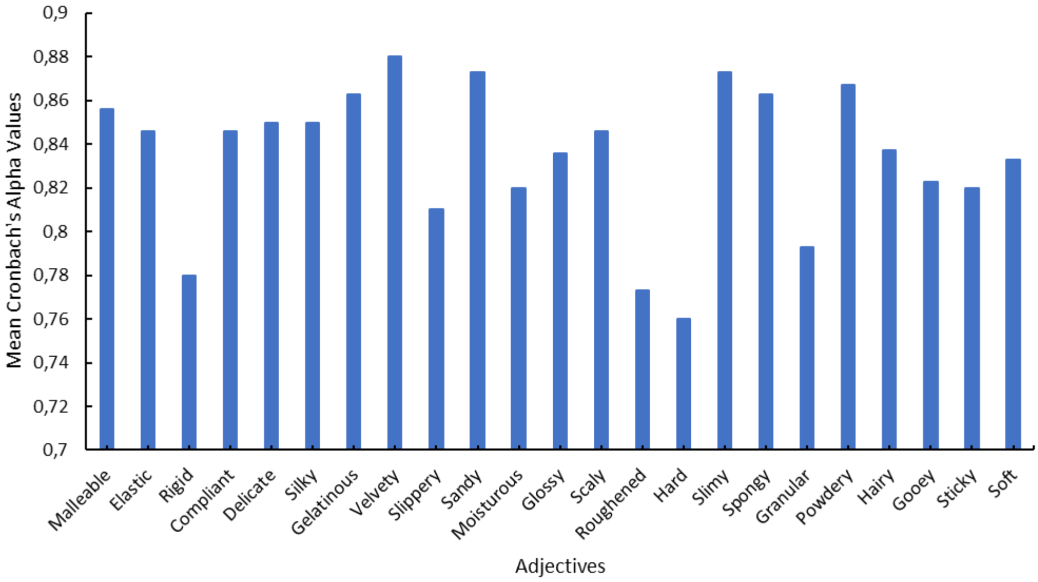
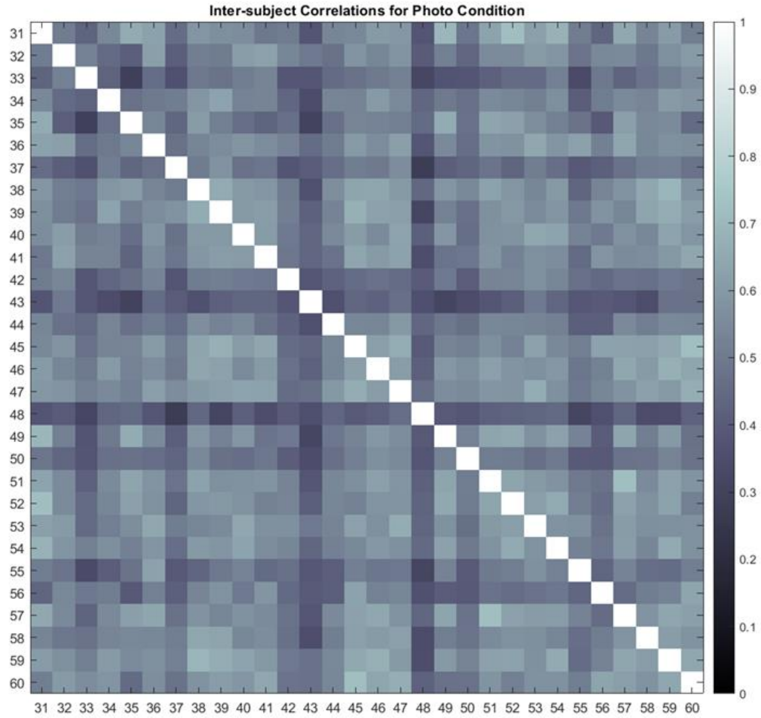
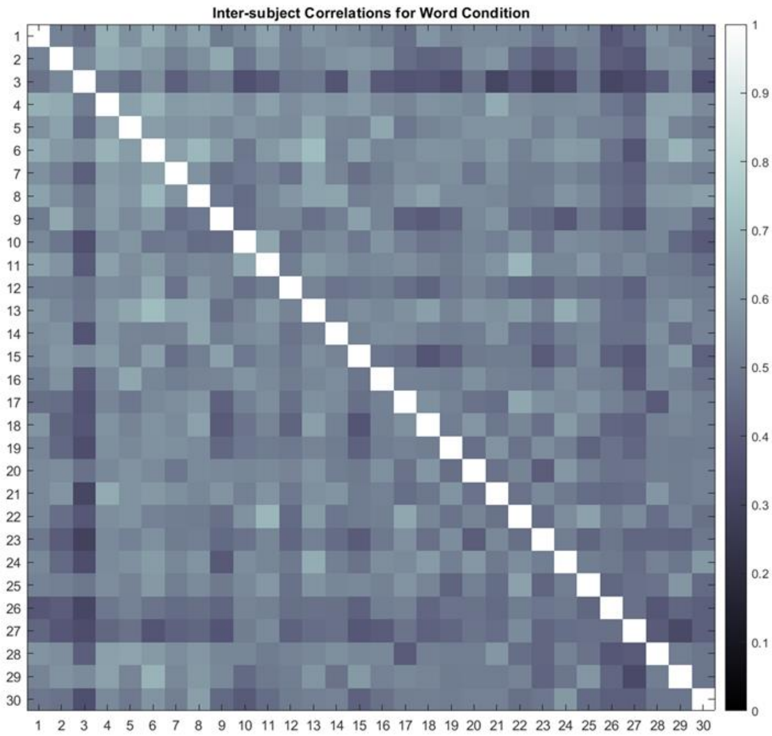


Figure 2.4. Bar plot depicting the overall Cronbach's alpha values for each adjective. Each bar represents an adjective, and the vertical axis represents the mean Cronbach's alpha values.

After calculating Cronbach's alpha values, we later mapped the correlations between participants within each condition. Figure 2.5 depicts correlation heat maps.



A



B

Figure 2.5. Inter-subject correlations for Photo (A) and Word (B) condition. Lighter colors indicate higher correlation and darker colors depict lower correlation.

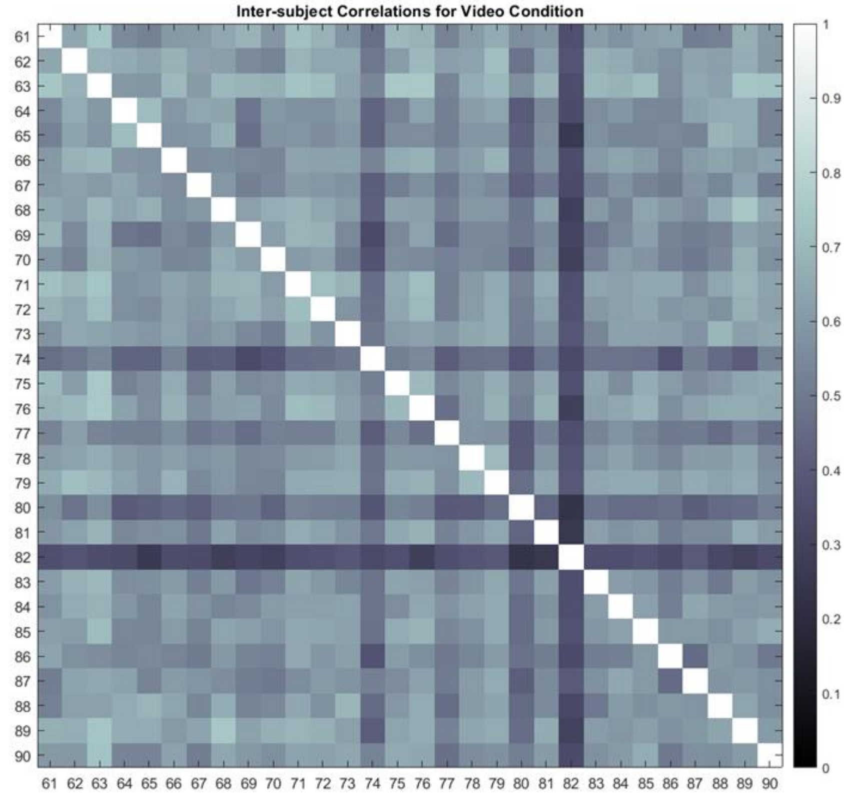
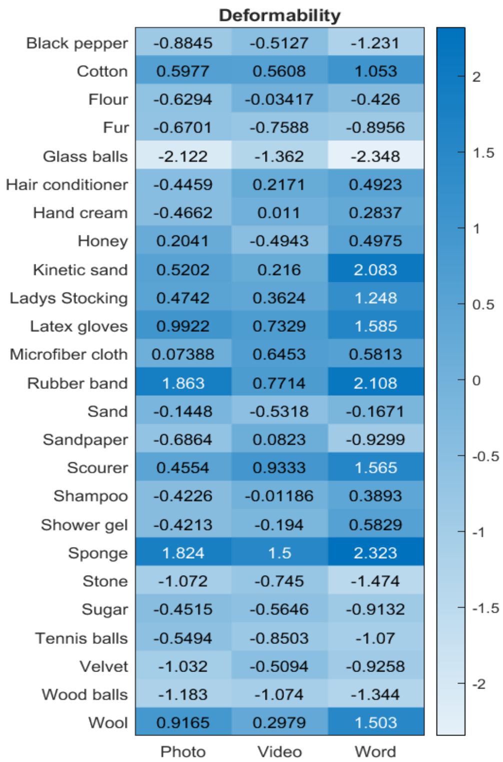


Figure 2.5. (continued) Inter-subject correlations for Video condition. Lighter colors indicate higher correlation and darker colors depict lower correlation.

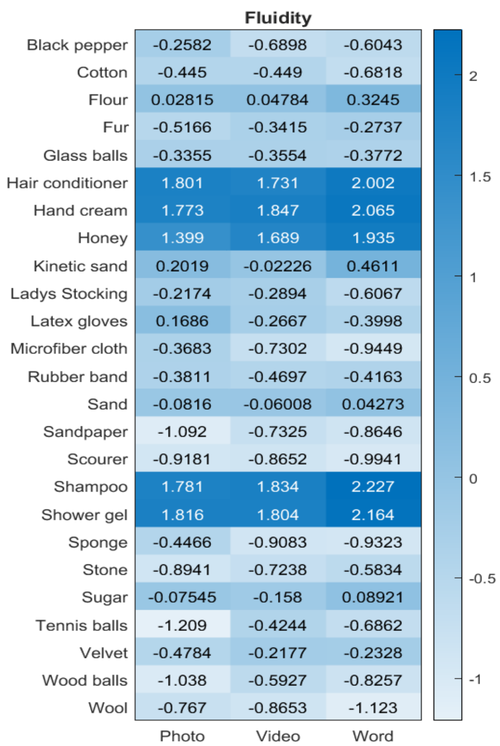
As can be seen from Figure 2.5, the correlations between participants were higher in video condition and lower in photo and word conditions. The difference between video and word, and video and photo might be an indicator of the additional help of mechanical cues over optic cues and prior knowledge while participants were judging the material properties. Due to the advantage of mechanical cues, participants might have perceived the material properties similarly, and thus might have been given similar ratings.

2.3.2.3. Combined Principal Component Analysis (PCA)

The first three PCAs were carried out based on adjectives for different conditions. Keyser-Meyer-Olkin (KMO) criterion was .32, .65, and .45 for the photo, video, and word conditions respectively. Even though the KMO values for photo and word conditions were borderline, Bartlett's test of sphericity revealed that the observed correlations between adjectives were meaningful for all three conditions, ($p<.001$): χ^2 (253) = 1017, χ^2 (253) = 1096, χ^2 (253) = 1036, respectively. Components were extracted by using varimax rotation and the number of components was based on the variance explained by each component. By doing this, we test how much of our data is fitted for Principal Component Analysis. Appendix E illustrates PCA Tables. After looking at the dimensionality of materials and adjectives and comparing them with the literature, we carried out a combined PCA with Bartlett scores in order to see the loadings of materials in each dimension without the separation of conditions (Cavdan et al., 2021). The reason that we combine the materials in all three conditions was to see the material dimensionality without the interference of the effect of condition, because when we conducted separate PCAs for each condition, it was seen that certain materials loaded on different dimensions depending on the condition. Thus, to continue carrying out our analysis, we conducted a combined PCA with Bartlett scores as done in Cavdan et al. (2021). The dimensions were named granularity, deformability, fluidity, and surface softness. The only different dimension was deformability, and it was named as such instead of roughness because the materials loaded on this dimension were rubber bands, sponge, scourer, latex gloves, and wool (instead of glass balls, tennis balls, wood balls, and sandpaper). Figure 2.6 shows the dimensionality of materials based on Bartlett scores.



A



B

Figure 2.6. Heat maps of the distribution of Bartlett scores for two dimensions from left to right: deformability (A) and fluidity (B).

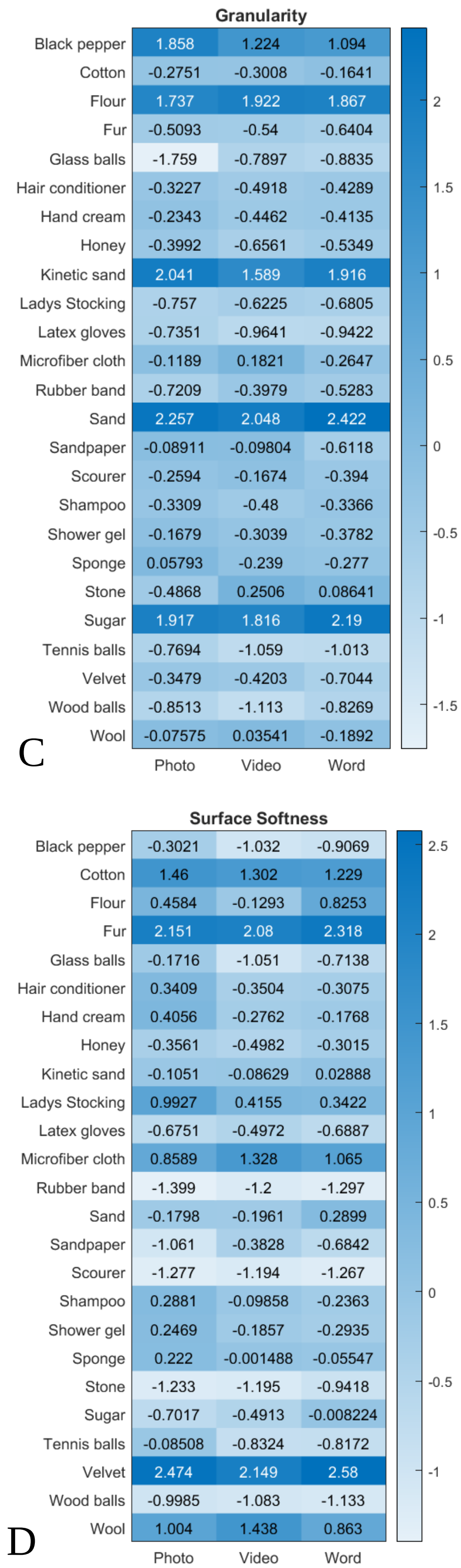


Figure 2.6. (continued) Heat maps of the distribution of Bartlett scores for two dimensions from left to right: granularity (C) and surface softness (D).

2.3.2.4. Mixed ANOVA with Dimensions

After carrying out a combined PCA and reducing the "Material" variable to the "Dimension" variable (To see the results of ANOVA conducted on raw data, see Appendix E and F), we carried out a 3 (condition) x 23 (adjective) x 4 (dimension) mixed ANOVA with the condition being between-group design, and adjective and dimension being within-group design. The results revealed that the main effect of condition was not statistically significant, $F(2, 87) = 0.891$, $p = .414$. Yet, the main effect of adjective ($F(10.79, 938.33) = 58.342$, $p < .05$, $\eta_P^2 = .401$) and the main effect of dimension ($F(2.2, 191.25) = 191.25$, $p < .05$, $\eta_P^2 = .519$) were statistically significant. The two-way interaction between condition and adjective was also significant, $F(21.57, 938.33) = 2.182$, $p < .05$, $\eta_P^2 = .048$. Further, the two-way interaction effect between condition and dimension, $F(4.4, 191.25) = 3.579$, $p < .05$, $\eta_P^2 = .076$ and between adjective and dimension, $F(21.63, 1882.01) = 272.704$, $p < .05$, $\eta_P^2 = .758$ were significant. The three-way interaction between condition, dimension, and adjective was significant, $F(43.26, 1882.01) = 2.513$, $p < .05$, $\eta_P^2 = .055$.

We then conducted post hoc analyses using t-Tests with Bonferroni Correction. The bar graphs of mean rating differences for each adjective based on dimensions were presented in Figure 2.7, Figure 2.8, and Figure 2.9.

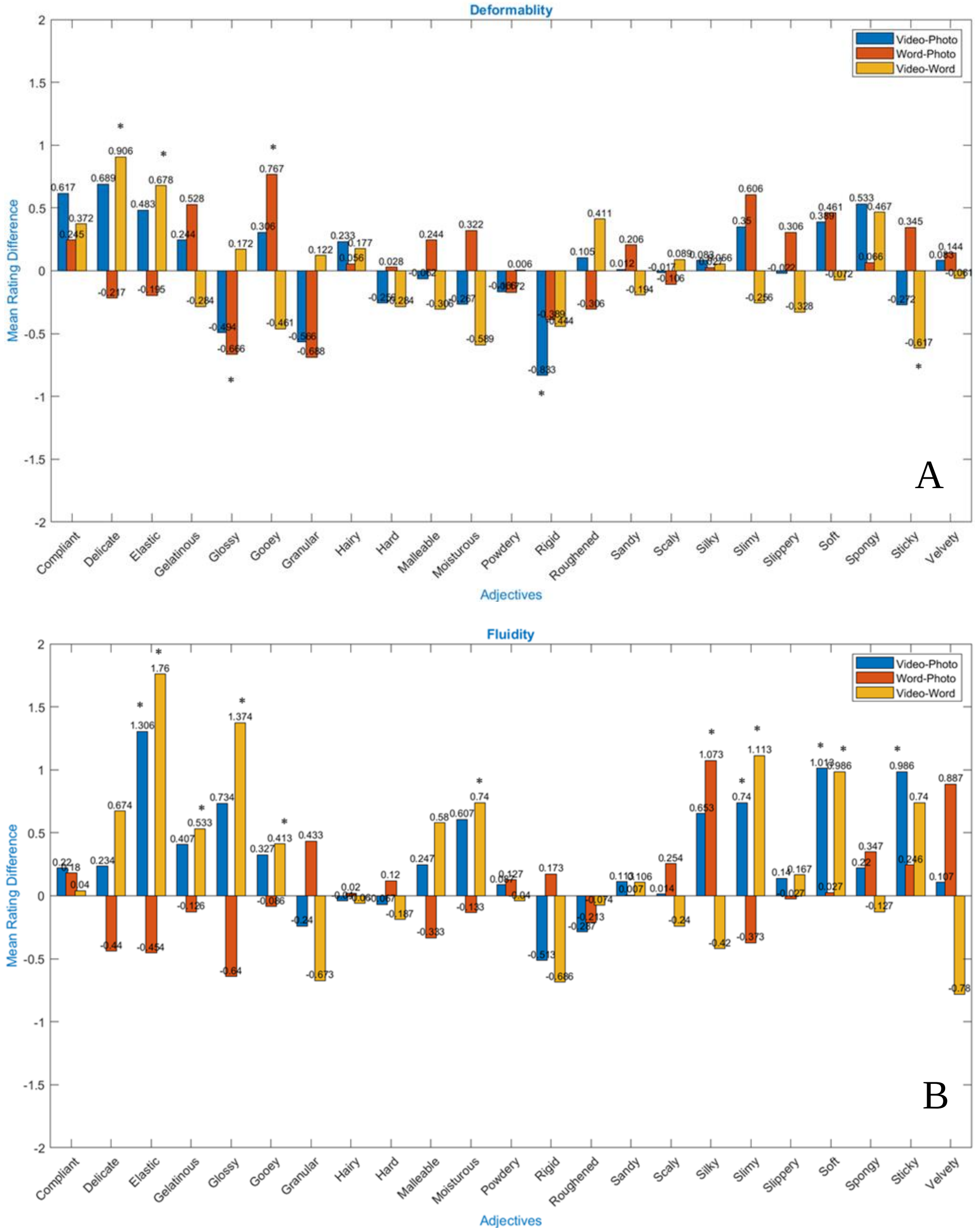


Figure 2.7. Bar graphs of mean rating differences for Deformability (A) and Fluidity (B) dimension grouped by condition. Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

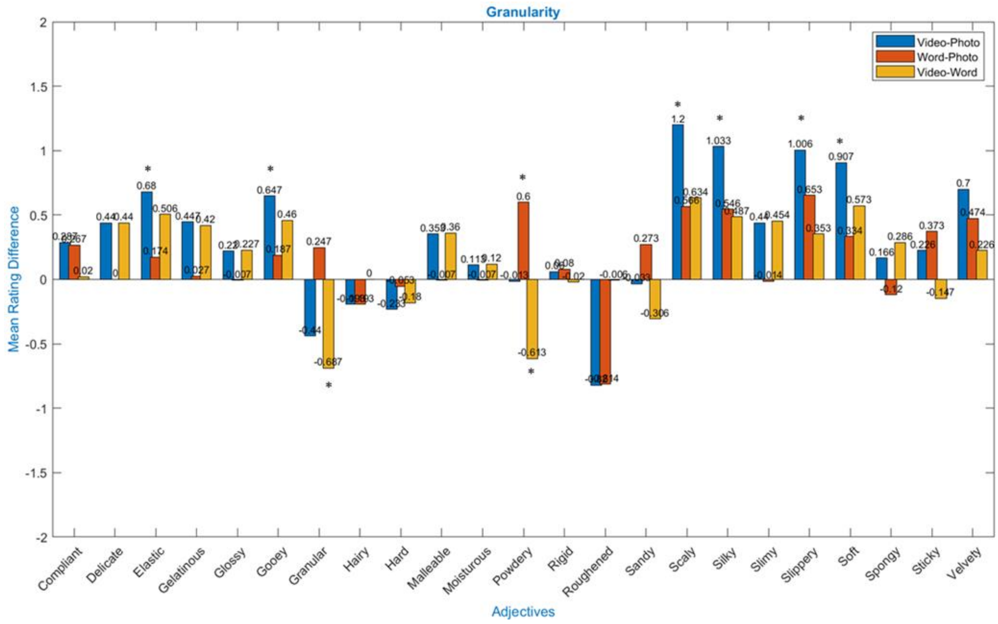


Figure 2.8. Bar graphs of mean rating differences for Granularity dimension grouped by condition. Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

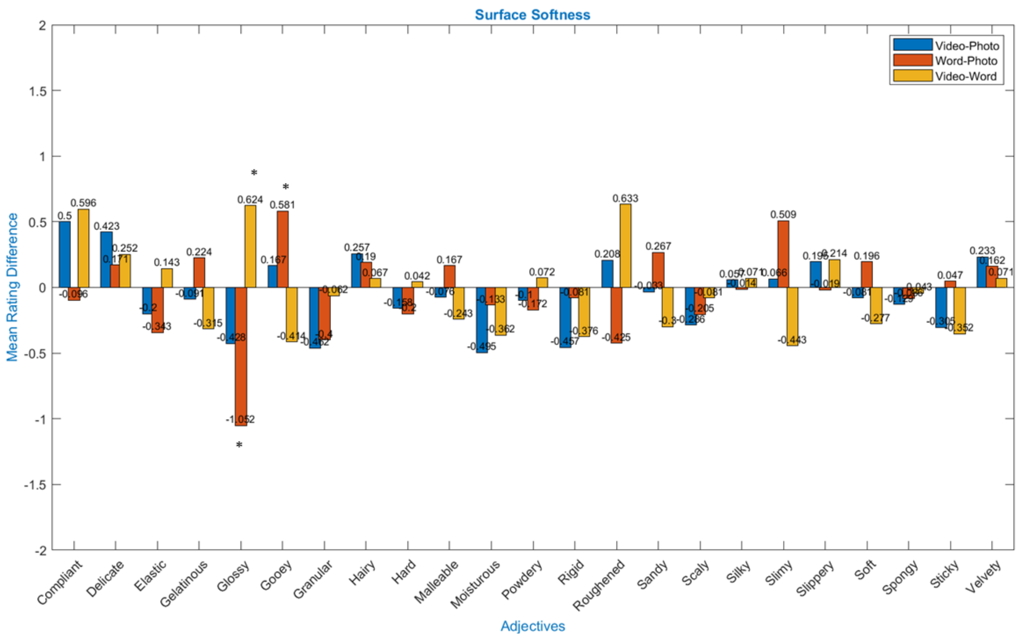


Figure 2.9. Bar graphs of mean rating differences for Surface Softness dimension grouped by condition. Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

2.3.3. Discussion

In this part of the thesis, we investigated (1) how much of the haptic information about material properties comes from memory in the absence of haptic exploration and (2) whether the mechanical cues have an advantage over prior knowledge and the optic cues. The results revealed that the main effect of the condition was not statistically significant, however, the main effect of adjectives, materials, and dimensions were significant. The last three significant effects were expected since (1) we included as many and diverse materials as possible to encompass a vast variety of everyday materials, and (2) we chose as many adjectives as possible to be able to describe various material properties. Therefore, it was inevitable that there would be significant differences within those materials and adjectives. Contrary to our expectations, this study did not find a significant main effect of condition. The absence of significant differences may partly be explained by the study conducted by Cavdan et al. (2021). In their research, the haptic perceptual space had high correlations with static visual and mechanical visual perceptual spaces, and further, the similarities between the two visual spaces were high as expected. When we explore a material either haptically or visually, these perceptual spaces gather information from the sensory modalities, yet the information is not encoded only in explored modality, it can also be associated to other modalities (Baumgartner et al., 2013; Bergmann Tiest & Kappers, 2007; Cavdan et al., 2021; Gallace & Spence, 2009; Lacey et al., 2007; Picard, 2006; Okamoto et al., 2013; Wijntjes et al., 2019; Xiao et al., 2016). Correspondence between perceptual modalities, and a possible explanation of our result, is a consequence of the information sharing across modalities (either amodal or multimodal in nature) by previous experience with the material.

There were notable differences, as the authors stated, between perceptual spaces when the effect of materials and adjectives were controlled in the analysis, which brings us to our results reporting a significant three-way interaction between condition, adjective, and material, and between condition, adjective, and dimension. Our results corroborate the ideas of Cavdan et al. (2021) who demonstrated that the difference between conditions was dependent upon the material (or dimension) and adjective in question. Specifically, adjectives of mechanical properties (e.g., Slimy, gooey, sticky, etc.) in video condition were significantly different from photo and word conditions for the fluid materials, such as hair conditioner, honey, and shampoo. However, this pattern was not the same for the other three dimensions (Granularity, deformability, and surface softness). For granularity, in addition to a few adjectives of mechanical properties (e.g., elastic, gooey, slippery, and soft), there were advantages of mechanical cues for the dimension-related adjectives, such as granular, powdery, and scaly. The ratings for these adjectives were significantly different in video condition than in the photo and/or word conditions. The other two dimensions depicted different patterns in which either photo condition or video condition had significantly different ratings from word condition for the adjectives of either mechanical or optic properties (e.g., Glossy). To sum up, we can conclude that our results have partially supported our hypothesis in which we assumed that the advantages of mechanical cues over prior knowledge and optic cues will be material (or dimension) and adjective specific.

CHAPTER 3

EXPERIMENTS 2 AND 3

3.1. Introduction

Ever since Lederman and Klatzky (1987) showed that people use stereotypical hand movements to haptically explore objects, researchers have focused on studying Exploratory Procedures (EPs) used during active exploration of soft/non-soft materials and their properties. Dövencioğlu et al. (2022) studied the dimensionality of softness perception and whether each softness dimension is correlated with a specific EP. They reported that softness perception is multidimensional, and each dimension (deformability, viscosity, surface softness, granularity, and roughness (control condition)) is associated with a specific EP (pressure, rub, rotate, run through, pull, stir, tap, and stroke). To elaborate, pressure and rubbing were mostly used while exploring deformable materials. Rotating and running through were used for granular materials. It was also observed that pulling and stroking were used for fluidity and surface softness dimensions respectively. The use of the other two EPs (stirring and tapping) did not significantly differ between dimensions. The importance of this study is that it specified which EP is most frequently used for which dimension.

What is more, Cavdan et al. (2019) investigated the dimensionality of perceived softness and how EPs are affected by the materials themselves. Their results suggested that softness is multidimensional, and this dimensionality influences the EPs that are used. People use different EPs while judging various softness-related properties and use them for materials from different dimensions. This study reveals that EPs can be adapted to learn more about material properties.

More importantly, while a specific hand movement (e.g., pressure) yields more information about a certain property (e.g., deformability), it might not be as informative for some other property (e.g., fluidity). Based on these studies, we structured our study to investigate whether an EP related to a specific dimension would provide people additional information about the properties of specific materials as compared to an EP that is not correlated with that dimension.

To this end, we used material videos in which there are 8 different materials x 2 different EPs, one is related to the material dimension and the other is not, thus in total we acquired 16 videos. We asked participants to rate these 16 videos based on 12 softness-related adjectives. We hypothesized that the EP associated with the dimension of the judged material (congruent EP) would generate higher ratings for the adjectives that are related to the given dimension than the EP that is not correlated with the given dimension (incongruent EP).

3.2. Experiment 2

3.2.1. Method

3.2.1.1. Participants

In the second experiment of the thesis, 30 participants (22 females, Mage = 23.1) who were undergraduate and graduate students at Middle East Technical University participated and were naïve to the purpose of the study. The participation was either voluntary or in exchange for course credit. Before the experiment, an informed consent form was presented to the participants, and they were also verbally informed that their participation is voluntary and that they can stop the process at any point without any reason. The participants had normal or corrected-to-normal vision, and none reported having any neurological or psychological disorder. The native language of the participants was Turkish, and their age range was between 18-30. The experiment took place in the Human Sciences building, and it lasted approximately 20 minutes for each participant. The study was approved by the Human Studies Ethical Committee of Middle East Technical University.

3.2.1.2. Experimental Setup

The experiment was designed and carried out in the laboratory setting by using MATLAB R2021b with Psychtoolbox extension. Participants sat in front of a lab computer and their responses were collected via a mouse connected to the computer. The distance of participants from the computer screen was kept the same across all participants (60 cm), and the lighting of the room was provided by a ceiling lamp. After participants were instructed about the task, they were presented with a trial task to understand the nature of the task, and later, participants were left alone in a soundproof room to continue the task itself.

3.2.1.3. Stimuli

The stimuli used in the study were the videos of 8 everyday materials. They were chosen from the materials that were used in the first experiment. In the second experiment, we only chose materials from four dimensions excluding the roughness dimension. Thus, the four dimensions were: deformability, surface softness, fluidity, and granularity. There were two materials from each dimension, and 8 in total.

The videos used in the experiment were recorded by the researcher herself and they had the same properties as the ones that were used in the first experiment. To adjust the videos according to the nature of the experiment, they were cut into 5 seconds long videos and only the related ones were used. The frame per second for videos was kept at 50 and their dimensions were 960 x 540 pixels. Later, by using MATLAB, the videos were cut into 250 frame clips, and they were resized as 640 x 360 pixels to reduce the size of the file and ease the display of the videos. In the experiment, videos were created from these frames automatically in the code just before the presentation.

Next, 16 videos were created from 8 different materials, and a certain hand movement (EP) was used for each video. For example, in the congruent condition of cotton, EP was stroking and in the incongruent condition, it was rotating (each one was a separate video) for cotton. These EPs were chosen depending on a study done by Dövencioğlu et al. (20). Table 3.1 lists the materials, and congruent and incongruent conditions.

Table 3.1. List of materials, and congruent and incongruent conditions

Materials	*Congruent Condition*	*Incongruent Condition*
Cotton	Stroking	Rotating
Wool	Stroking	Pulling
Hair Conditioner	Pulling	Stroking
Shower Gel	Pulling	Rotating
Kinetic Sand	Run Through	Pulling
Flour	Run Through	Pressure
Scourer	Pressure	Stroking
Sponge	Pressure	Rotating

In the study, there were two experimental conditions: one was the congruent condition in which the EP was correlated with the material dimension, and the other one was the incongruent condition in which the EP was not related to that material dimension. For example, pulling has been found to be correlated with fluidity dimension (Dövencioğlu et al., 2022), thus we chose that EP for fluid materials in the congruent condition. Yet, they did not find any correlation between rotating or stroking with any dimension, so they were used as incongruent hand movements. Here, it is important to underline that even though rotating or stroking are not related to the fluidity dimension, the first is correlated with the granularity dimension and the second one is related to surface softness. Hence, while an EP can be congruent for one dimension, it can be an incongruent movement for the others. Further, stroking was chosen as the congruent EP for surface softness dimension; rotating and pulling were chosen as the incongruent EPs. In the granularity dimension, run-through was the congruent EP; and pulling and pressure were selected as the congruent EPs. Lastly, in the deformability dimension, pressure was chosen as the congruent EP; stroking, and rotating as the incongruent EP.

3.2.1.4. Experimental Procedure

At the center of the screen, participants viewed the videos looping every 5 seconds and they rated the materials based on the question that was displayed on top of the videos (e.g., Bu malzeme ne kadar “tanecikli”?) by using a rating bar ranging from 1 to 7 under the videos via scrolling a mouse. The order of both videos and the questions was randomized for every participant. We ensured that participants answered every question for every material by not letting them skip the video without rating it.

The task of the participants was to rate these 16 videos based on 12 softness-related adjectives which were chosen among 23 adjectives in the first experiment (e.g., Bu malzeme ne kadar “esnek”?). The selection was based on PCA carried out on adjectives and three adjectives in each component (i.e., dimension) that has the highest loadings were chosen among others. Table 3.2 lists the adjectives. The rating was obtained from participants by using a Likert scale ranging from 1 to 7 in which 1 means that the adjective does not define the material/is not correlated and 7 means that the adjective defines the material/is highly correlated. What is more, we requested participants to pay attention to the videos and to give their answers accordingly.

Table 3.2. List of adjectives in the questions and corresponding dimensions

Deformability	**Surface Softness**	**Fluidity**	**Granularity**
Esnek-Elastic	*Kadifemsi-Velvety*	*Kaygan-Slippery*	*Kum gibi-Sandy*
Güç uygulanabilir-Compliant	*Tüylü-Hairy*	*Vıcık vıcık-Gooey*	*Toz gibi-Powdery*
Biçimlenebilir-Malleable	*İpeksi-Silky*	*Yapışkan-Sticky*	*Tanecikli-Granular*

We hypothesized that there will be significant differences between the congruent and the incongruent conditions for the adjectives that represent the dimension in question, in favor of the congruent condition. Therefore, we expected to see significant differences between the conditions of "compliant, elastic, and malleable" in the deformability dimension; of "gooey, slippery, and sticky" in the fluidity dimension; of "granular, powdery, and sandy" in granularity dimension; and of "hairy, silky, and velvety" in surface softness dimension.

3.2.2. Results

3.2.2.1. Analysis Plan

The data were analyzed by using R Studio and visualized via MATLAB R2021b. We conducted a 2 (Congruency: congruent vs. incongruent) x 12 (Adjective: biçimlenebilir, esnek, güç uygulanabilir, ipeksi, kadifemsi, kaygan, kum gibi, tanecikli, toz gibi, tüylü, vıcık vıcık, ve yapışkan) x 8 (Material: cotton, wool, hair conditioner, shower gel, kinetic sand, flour, scourer, sponge) repeated measures ANOVA in R Studio to see whether there is any significant difference between the conditions and whether the interaction effect would yield a significant difference. Later, to observe the differences between conditions based on materials and adjectives, we visualized the data in MATLAB by creating mean graphs across all materials for each adjective.

3.2.2.2. Analysis of Variance (ANOVA)

We carried out a 2 (Congruency) x 12 (Adjective) x 8 (Material) repeated measures ANOVA. The results revealed that the main effect of congruency was statistically significant, $F(1, 29) = 9.784$, $p = .004$, $\eta_p^2 = .252$. Additionally, the main effect of adjective ($F(4.5, 130.38) = 19.646$, $p < .05$, $\eta_p^2 = .404$) and the main effect of material ($F(3.16, 91.52) = 45.645$, $p < .05$, $\eta_p2 = .611$) were statistically significant. The two-way interaction of congruency and adjective was also significant, $F(11, 319) = 5.628$, $p < .05$, $\eta_p^2 = .163$. Further, the two-way interaction effect of congruency and material, $F(4.21, 121.99) = 8.064$, $p < .05$, $\eta_p^2 = .218$ and of adjective and material, $F(77, 2233) = 67.277$, $p < .05$, $\eta_p^2 = .699$

were significant. The three-way interaction between congruency, material, and adjective was significant, $F(77, 2233) = 1.945$, $p < .05$, $\eta_p^2 = .063$.

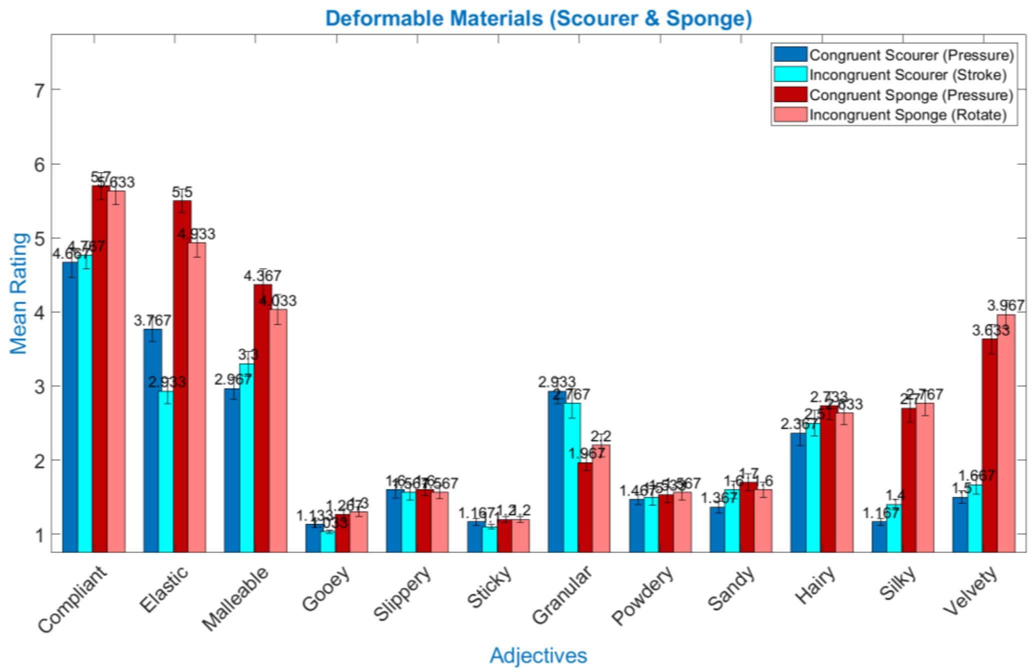


Figure 3.1. The mean rating graphs of two deformable materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material and the congruent and the incongruent EP for the material.

As can be seen from Figure 3.1, there were no significant differences between the conditions for any of the adjectives and the materials. The overall ratings given by the participants illustrate a pattern for the material "Sponge". We can see that the ratings in congruent conditions are higher than the ones in the incongruent conditions for deformable adjectives "compliant, elastic, and malleable", which were the three adjectives that we chose based on PCA carried out in experiment one (See Appendix). In addition to these adjectives, the same pattern is observed for "hairy, sandy, and slippery". The pattern for "Scourer" does not depict a clear pattern as "Sponge". For the deformable adjectives, only "elastic" demonstrates the same pattern as "Sponge". For other adjectives expect "gooey, granular, slippery, and sticky" and a reverse pattern is observed.

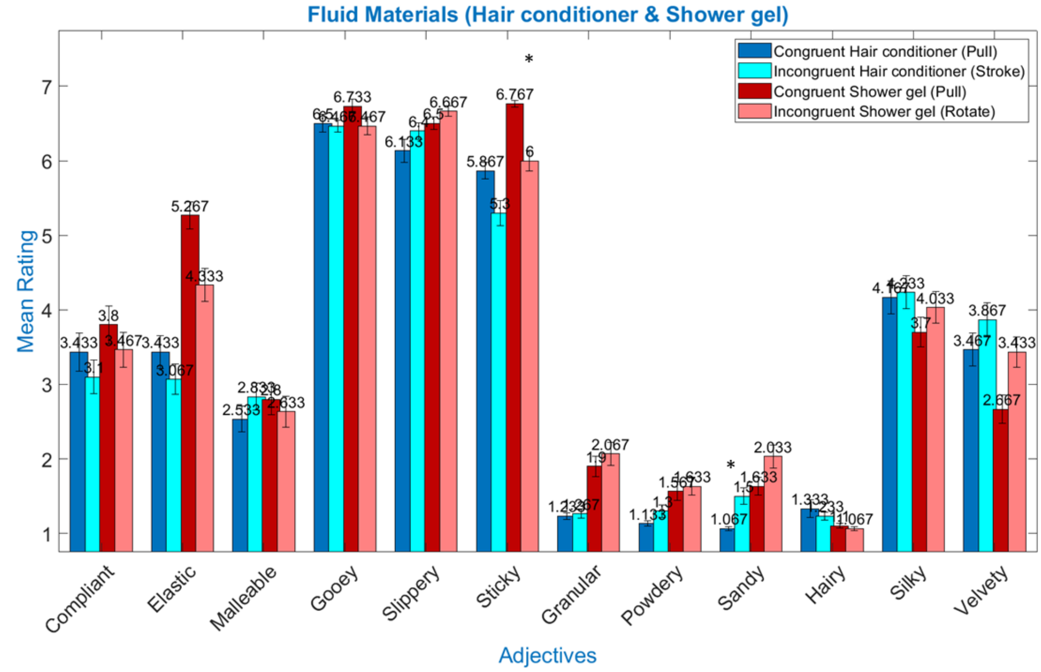


Figure 3.2. The mean rating graphs of two fluid materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material and the congruent and the incongruent EP for the material.

Figure 3.2 illustrates that there was a significant difference between the congruent and incongruent conditions of “Hair conditioner” for the adjective “sandy”. Participants gave higher ratings in the incongruent condition than in the congruent condition. However, because “sandy” is an adjective corresponding to the dimension “Granularity” based on PCA in the first experiment and “Hair conditioner” is a material that does not manifest any granular property, the unexpected rating difference might be a result of conceptual understanding of the adjective “sandy” of some of the participants. When we look at the individual rating graphs, this conclusion is supported. Seven out of 30 participants gave higher ratings for the incongruent condition and the rating difference of two of these seven participants was four between the conditions. Thus, according to these data, we can infer that the overall effect is in fact carried by a very small number of participants.

For the “Shower gel”, the only significant difference was in the adjective “sticky”. The mean rating in the congruent condition was higher than the mean rating in the incongruent condition. This result is in line with our hypothesis because “sticky” was observed as revealing viscoelastic properties of materials, therefore it is considered a fluid (viscous) adjective, and because “Shower gel” is a fluid material, we expected to see a higher rating in the congruent condition for viscous adjectives which are “gooey, sticky, and slippery”. Yet, we did not observe significant differences for “slippery and gooey” which might be a result of EP choice. We will discuss these results further in the discussion.

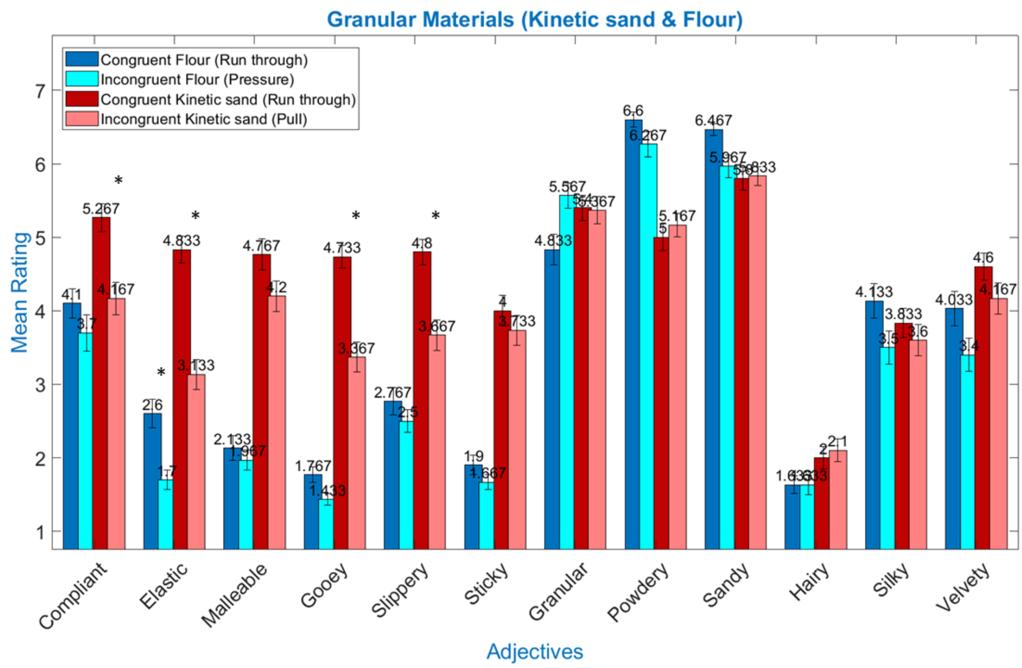


Figure 3.3. The mean rating graphs of two granular materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material and the congruent and the incongruent EP for the material.

As can be seen from Figure 3.3, the only significant difference for the material "flour" was for the adjective "elastic". The congruent condition revealed a higher rating than the incongruent condition. Since "elastic" is considered a deformable adjective and "flour" is a granular material, we did not expect to see this rating difference. This rather unexpected result may be due to EP selection. Running flour through fingers might create a percept that flour is an elastic material and therefore, it manifests such motion. While, in fact, the motion can be explained by its granular feature.

The significant differences between the conditions of the material "Kinetic sand" were for the adjectives "compliant, elastic, gooey, and slippery", and for all of the adjectives, higher ratings were given for the congruent conditions. The nature of the "Kinetic sand" is viscoelastic, thus it manifests both viscous and deformable properties in addition to granular properties. Due to this fact, it is not surprising that we observed significant differences between the conditions of deformable adjectives (compliant and elastic) and viscous adjectives (gooey and slippery). Yet, we did not find any significant difference for granular adjectives which are "granular, powdery, and sandy".

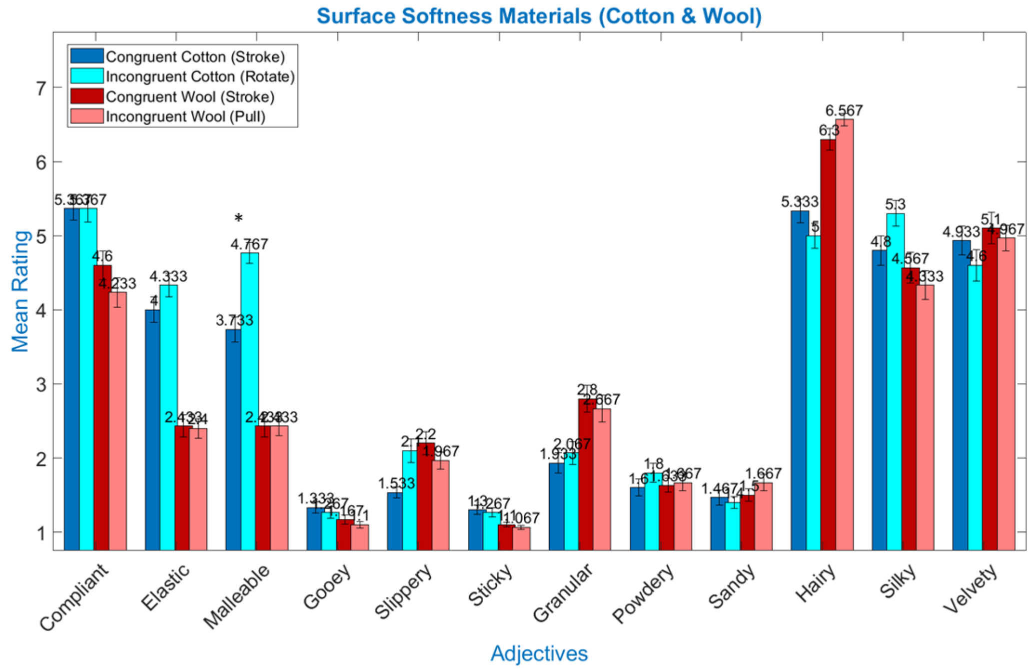


Figure 3.4. The mean rating graphs of two surface softness materials in the study. The x-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material and the congruent and the incongruent EP for the material.

As Figure 3.4 depicted, the only significant difference was for “cotton” for the adjective “malleable”. The incongruent conditions received higher ratings than the congruent condition. This unexpected result might be due to EP choice because rotating that was chosen as incongruent EP for “cotton” could expose deformable properties regarding that in the video a cotton piece was held and manipulated as compared to stroking which is just touching the material without holding or manipulating it. Therefore, this discrepancy between the EPs chosen brought about rating differences in favor of the incongruent condition. Other than this adjective, we did not find any significant difference for surface softness adjectives which are "hairy, silky, and velvety".

3.2.3. Discussion

In the study, we hypothesized that there would be significant differences between the conditions within each adjective that was related to the dimension from which the material in question was chosen. Nevertheless, in the deformability dimension, we did not find any significant difference between the conditions of deformable adjectives (complaint, elastic, and malleable). The chosen EPs might be another reason for obtaining nonsignificant results. Even though congruent EP was found to be correlated with deformability dimension, the incongruent EPs also manifest certain material qualities, thus they could play a role as a confounding variable in the study.

In the fluidity dimension, the only significant result that was in line with our hypothesis was that the conditions of "sticky" revealed a significant difference for "shower gel". The other significant result was between the conditions of "sandy" for "hair conditioner". It seems possible that these results might be carried out by a small number of participants. Because the ratings of only seven out of 30 participants were higher for the incongruent condition and the rest of the participants gave similar ratings for each condition.

Next, in the granularity dimension, kinetic sand demonstrated a different pattern contrary to our expectations. Even though kinetic sand seems like sand, it manifests viscoelastic properties when it is observed through dynamic cues. Due to its unnatural properties, it might be considered as a half fluid and half deformable material by the participants, which in turn affected the ratings related to deformable ("compliant and elastic") and viscous adjectives ("gooey and slippery"). The congruent EP yielded higher ratings than the incongruent EPs for these four adjectives. The only significant difference for "flour" was between the conditions of "elastic". The only explanation for this finding could be explained in a similar matter to the results of “sandy” for “hair conditioner”. Only the ratings of five out of 30 participants yielded higher rating differences between conditions.

Finally, in the surface softness dimension, the only significant difference was between the conditions of "malleable" for "cotton", in favor of the incongruent condition. This might have happened since the incongruent EP was rotating, which requires holding the material and manipulating it as compared to stroking, which does not require any grasping movement. It might also look like pressure. Therefore, holding and rotating the material between the fingers could lead participants to think that it is malleable. We did not observe any hypothesized difference between the conditions.

Overall, the explanation behind the findings of the study that was in contradiction with our hypothesis could be the EP selection. Although the incongruent EPs were not correlated with the materials in the study, they were related to other dimensions and materials, therefore we can assume that they still bring out certain material properties (e.g., run-through reveals how much granular a material is). The manifestation of material properties by the incongruent EP could interfere with the perception of participants and could create a complex pattern of answers, some of them relied upon prior knowledge and some of them were the result of observing the video.

The findings of the study demonstrated a contradictory result to our hypothesis. Therefore, to understand whether the results were due to our EP selection, we carried out another experiment in which we changed the EPs and kept the incongruent EP constant for all the materials. In the next section, we will explain the details of the study.

3.3. Experiment 3

3.3.1. Method

3.3.1.1. Participants

25 naïve participants (16 females, Mage = 25.32) participated in the third part of the thesis study. They were undergraduate and graduate students at Middle East Technical University and their participation was voluntary. Before the

experiment, an informed consent form was given to the participants to inform them about the study and to ensure that their data would be kept confidential. In addition to the form, they were verbally informed about the task and that they can stop the experiment at any point for any reason. The participants had normal or corrected-to-normal vision and they did not report any neurological and/or psychological disorders. The native language of the participants was Turkish, and their age range was between 18 and 30 years old. The experiment took place in the Human Sciences building, and it lasted approximately 20 minutes for each participant. The study was approved by the Human Studies Ethical Committee of Middle East Technical University.

3.3.1.2. Experimental Setup

The experiment was designed and carried out in the laboratory setting by using MATLAB R2021b with Psychtoolbox extension. Participants sat in front of a computer and their responses were collected via a mouse connected to the computer (1920x1200 display resolution, 14″). The distance of participants from the computer screen was fixed for all participants (60 cm), and the lighting of the room was provided by a ceiling lamp. After participants were instructed about the task, they were presented with a trial phase to understand the nature of the task, and participants, then, were left alone in a soundproof room to continue the task.

3.3.1.3. Stimuli

The stimuli used in the study were chosen among the materials which were used in the first study and except for two materials, they were different from the ones chosen for the second study. The rationale behind keeping these two materials constants was that they are the materials that best describe the properties of the dimensions that they were chosen from. 'Sponge' is the material that is highly correlated with deformability dimension and 'Kinetic Sand' is the material that is loaded on granularity dimension having viscoelastic properties. The properties of videos and frames were the same as in the second experiment. The design of the experiment was also the same as the second one, except for a change in the incongruent condition. For all 8 materials, EP in incongruent condition was stirring. We selected “stirring” because it is found not to have an association to a specific dimension (Dövencioğlu et al., 2022), and also, it was rarely coded in BORIS, which is a software to code EPs and their frequency, compared to other EPs. For the congruent condition, EPs were chosen based on their relation to that dimension. For surface softness, the congruent EP was stroking; for fluidity, it was pulling; for granularity, it was run-through; and for deformability, it was pressure. Table 3.3 shows the material list, and congruent and incongruent conditions.

Table 3.3. List of materials, and congruent and incongruent conditions

Materials	*Congruent Condition*	*Incongruent Condition*
Fur	Stroking	Stirring
Velvet	Stroking	Stirring
Hand Cream	Pulling	Stirring
Honey	Pulling	Stirring
Kinetic Sand	Run Through	Stirring
Sugar	Run Through	Stirring
Sponge	Pressure	Stirring
Wool Balls	Pressure	Stirring

3.3.1.4. Experimental Procedure

The experimental procedure was the same as Experiment 2. There were two EP congruency conditions, eight materials, and 12 adjectives. The task of the participants was to rate 16 videos based on 12 softness-related adjectives (e.g., Bu malzeme ne kadar esnek?). The rating was obtained from participants by using a rating bar ranging from 1 to 7 in which 1 means that the adjective does not define the material/is not correlated and 7 means that the adjective defines the material/is highly correlated. Look at Table 3.1 to see the adjective list.

We instructed participants to rate the materials based on what they see on the screen, thus it was a crucial part of the experiment that they paid attention to the videos, and the interaction of the hand with the material in that video.

We hypothesized that, in Experiment 2, there will be differences between the congruent and the incongruent conditions for the adjectives that represent the dimension in question, in favor of the congruent condition. Therefore, we expected to see higher ratings in the congruent condition of "compliant, elastic, and malleable" in the deformability dimension; of "granular, powdery, and sandy" in the granularity dimension; and of "hairy, silky, and velvety" in surface softness dimension. As opposed to these hypotheses, we did not expect to see any significant differences between the conditions of viscous adjectives because stirring is an EP that also reveals the viscous properties of the materials. Even though Dövencioğlu et al. (2022) did not observe any significant correlation of that EP with the fluidity dimension, everyday experience draws another picture regarding this EP interacting with the fluids.

3.3.2. Results

3.3.2.1. Analysis Plan

The data was analyzed by using R Studio and visualized via MATLAB R2021b. We conducted a 2 (Congruency: congruent vs. incongruent) x 12 (Adjective) x 8 (Material: fur, velvet, hand cream, honey, kinetic sand, sugar, sponge, wool balls) repeated measures ANOVA in R Studio to see whether there are any significant differences between the conditions and whether the interaction effect would yield a significant difference. Later, to observe the differences between conditions based on materials and adjectives visually, we created bar graphs from the mean scores of the data in MATLAB. To conduct post hoc analysis, we planned to use Bonferroni correction.

3.3.2.2. Analysis of Variance (ANOVA)

We carried out a 2 (Congruency) x 12 (Adjective) x 8 (Material) repeated measures ANOVA. The results revealed that the main effect of congruency was statistically significant, $F(1, 24) = 6.825$, $p = .015$, $\eta_p^2 = .221$. Additionally, the main effect of adjective ($F(5.06, 121.50) = 16.824$, $p < .05$, $\eta_p^2 = .404$) and the main effect of material ($F(4.66, 111.85) = 15.716$, $p < .05$, $\eta_p^2 = .396$) were statistically significant. The two-way interaction of congruency and adjective was also significant, $F(11, 264) = 4.369$, $p < .05$, $\eta_p^2 = .154$. Further, the two-way interaction effect of congruency and material, $F(7, 168) = 2.276$, $p < .05$, $\eta_p^2 = .087$ and of adjective and material, $F(77, 1848) = 64.851$, $p < .05$, $\eta_p^2 = .730$ were significant. The three-way interaction between congruency, material, and adjective was significant, $F(77, 1848) = 2.427$, $p < .05$, $\eta_p^2 = .092$.

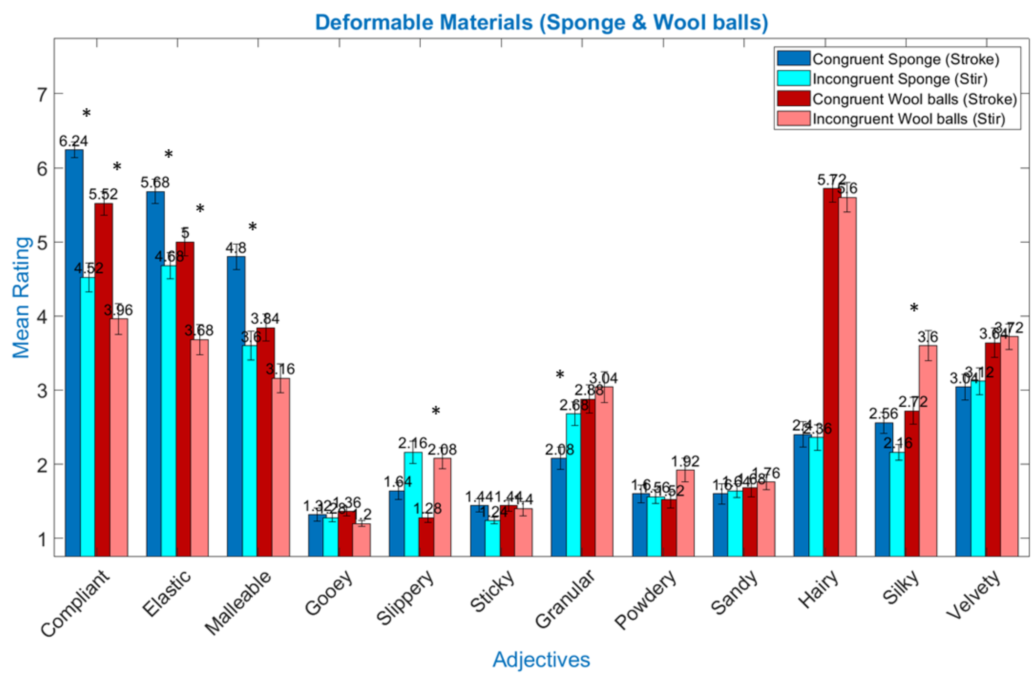


Figure 3.5. The mean rating graphs of two deformable materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material.

Figure 3.5 depicts the mean ratings across all participants for deformable materials and all the adjectives in the study. As it can be seen, for the material "sponge", all three deformable adjectives (compliant, elastic, and malleable) were statistically significant, and the congruent condition yielded higher ratings than the incongruent condition. In addition to that, the adjective "granular" revealed a significant difference in which the incongruent condition received higher ratings. We assumed that this resulted from the material itself in the video because the "sponge" in the video consisted of six pieces ripped off from a whole sponge. Due to the appearance of the sponge in the video, participants might rate it as granular in the incongruent condition that we stir the sponge pieces as compared to pressing in the congruent condition. For "wool balls", "compliant" and "elastic" also yielded significantly higher ratings in the congruent condition. Additionally, we observed that participants rated "wool balls" as more silky and slippery in the incongruent conditions which we concluded that they were brought about by the fact that in the incongruent condition, stirring the material caused it to seem slippery and silky because it easily moved on the surface of the glass plate.

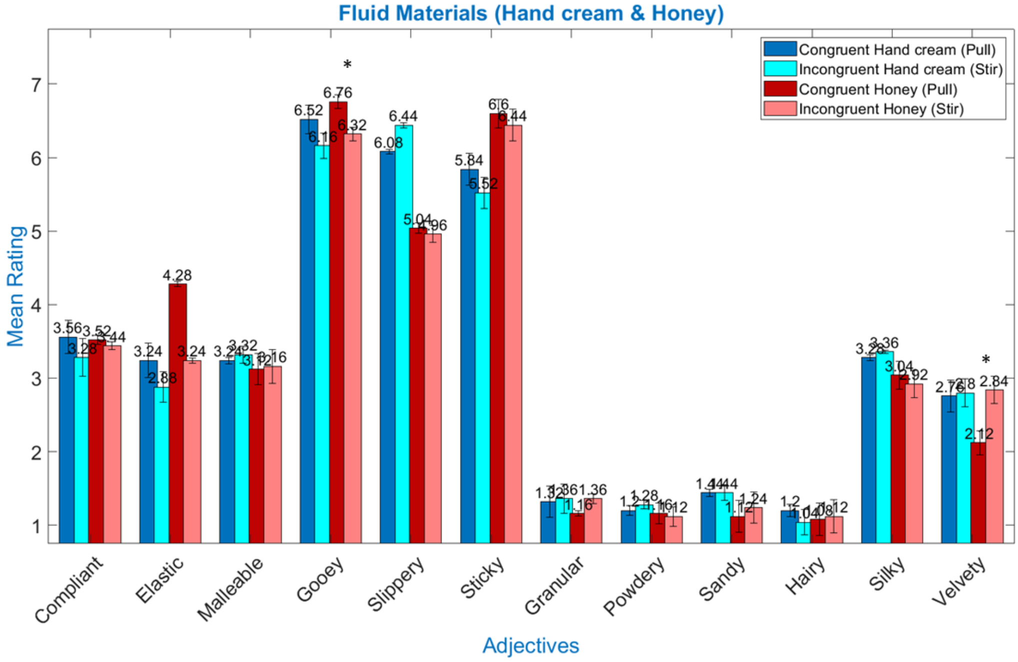


Figure 3.6. The mean rating graphs of two fluid materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material.

As Figure 3.6 illustrates the only two significant differences were between the conditions of “gooey” and “velvety” for “honey”. For “gooey”, it was in line with our hypothesis because a fluid material yielded higher ratings in the congruent condition of a viscous adjective. Yet, we did not hypothesize to find any significant difference for “velvety” still, not the congruent, but the incongruent condition received higher ratings. We will discuss this further in the discussion section.

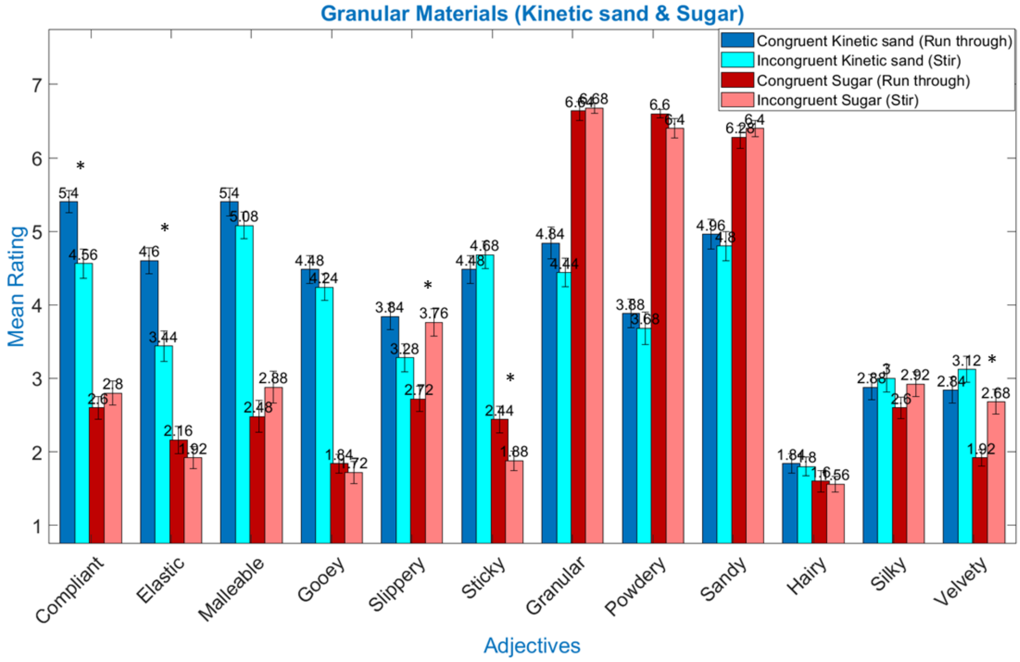


Figure 3.7. The mean rating graphs of two granular materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material.

Figure 3.7 demonstrates that "compliant" and "elastic" yielded significantly higher ratings in the congruent condition of "kinetic sand". Unexpectedly, kinetic sand did not manifest viscous properties in Experiment 3 and were in contradiction to the hypothesis that we proposed based on Experiment 2. For "sugar", the adjectives "slippery" and "velvety" revealed that the ratings in the incongruent conditions were significantly higher than in the congruent conditions. For “sticky”, this pattern was reversed. The ratings in the congruent condition were higher than in the incongruent condition.

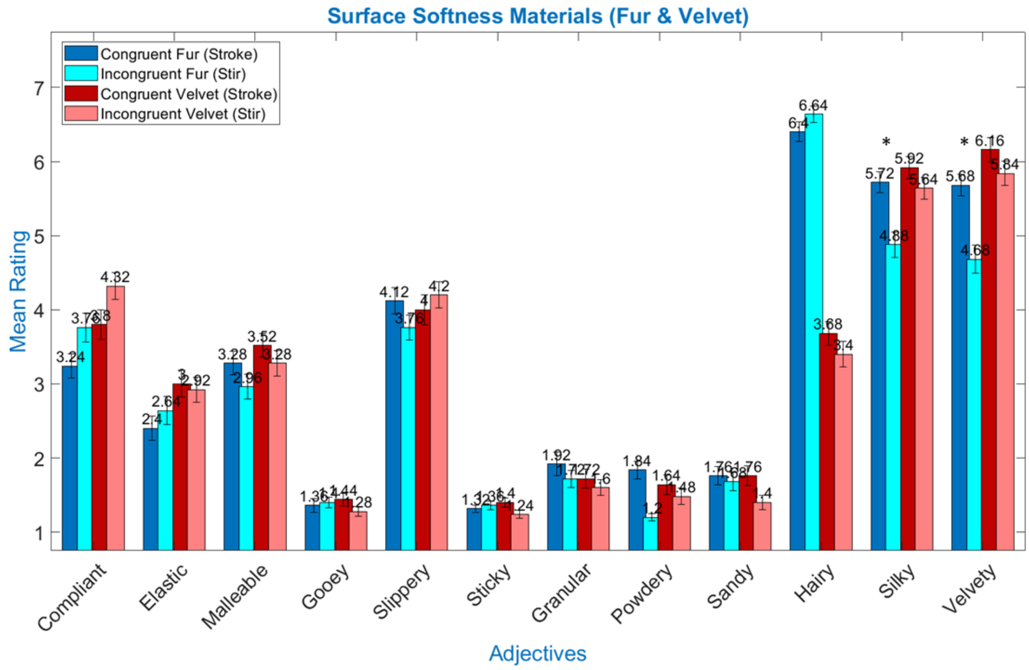


Figure 3.8. The mean rating graphs of two surface softness materials in the study. The X-axis shows adjectives, and the y-axis shows the mean rating across all participants given for that condition. For each bar color, the darker one represents the congruent condition for that material and the lighter one represents the incongruent condition. The legend depicts which color represents which material.

As it can be seen from Figure 3.8, the significant differences between the conditions of "silky" and "velvety" for "fur" were supporting our hypothesis because "silky" and "velvety" are two of three surface softness adjectives (silky, velvety, and hairy). The significantly higher ratings in the congruent condition of "powdery" were unexpected and will be discussed in the next section. For "velvet", we did not observe any significant difference within the adjectives.

3.3.3. Discussion

Here, we hypothesized that for the adjectives representing one of the four dimensions, the ratings in the congruent condition would yield higher evaluations than the ones in the incongruent conditions. In the deformability condition, "sponge" displayed the same pattern that we proposed. For "compliant, elastic, and malleable", the congruent condition yielded higher ratings. Further, this difference can be explained in part by that the material “sponge” that we used in the study was divided into six pieces and it might be considered as a granular material. This discrepancy could be attributed to the fact that the incongruent condition was stirring, therefore while the hand that interacts with the materials in the study engaged in all six pieces, the congruent EP “pressure” only dealt with one piece of sponge. The difference in the EPs and the interaction with the material could lead to such rating differences. “Wool balls” also illustrated a similar pattern to “sponge”. The adjectives “compliant and elastic” were rated higher in the congruent conditions compared to the incongruent conditions. Nevertheless, we observed two other significant differences, which one in “slippery” and the other one was in “silky”, both in favor of the incongruent conditions. Here, we claimed that this difference is likely to be related to the chosen EP. While the experimenter was stirring “Wool balls”, they were slipping on the surface of a glass plate, and this might create a percept suggesting that they were slippery, and thus silky (Silky might be approached as being slippery because of its smoothness properties).

In the fluidity dimension, only "gooey" and "velvety" revealed significant differences between the conditions for "honey". The ratings of "gooey" were higher in the congruent condition and of "velvety", they were higher in the incongruent condition. The observed difference for "gooey" might be attributed to that pulling the material between the fingers revealed more information about how gooey it is in comparison to the information provided by stirring. For “velvety”, stirring revealed higher ratings than pulling which might be due to that stirring is a fluidity related EP, and that might be a reason that we don’t observe any difference between pulling and stirring for fluid materials. In the granularity dimension, “kinetic sand” displayed elastic properties by yielding higher ratings in the congruent conditions of “compliant and elastic”. These results seem to be consistent with Experiment 2. In contrast to earlier findings, however, here we did not find any significant difference for viscous adjectives. The explanation might be dependent upon the EP change between the studies, which can be an indication that using different EPs alters the perception of material properties. For "sugar", we observed significant differences between the conditions of "slippery, sticky, and velvety". These differences were unexpected for us since sugar is a granular material. Yet, it might be that stirring is generally related to the viscous properties of the materials and using this EP might be interfering with the perception of the materials and altering them.

Finally, in the surface softness dimension, for “fur”, the adjectives “powdery” and “silky” demonstrated that there are significant differences between the conditions, in favor of the congruent one. As we proposed the significant difference for “silky” was expected, yet for “powdery” it was not predicted.

We will discuss further in the next chapter why we did not observe the hypothesized results and why we did observe these unexpected significant differences.

CHAPTER 4

GENERAL DISCUSSION

4.1. Overview

The current thesis intends to investigate the effect of prior knowledge and visual cues over the perceived softness, and how exploratory procedures affect our perception of the material properties. I searched for answers to (1) “What are the roles of prior knowledge and visual cues on the perceived softness?”, (2) “Do mechanical cues reveal additional information about the material properties, such as how gooey it is?” or in other words “Do mechanical cues have an advantage over the optic cues (photographs) and/or prior knowledge (names of materials)?”, (3) “Are these differences dimension- and adjective-specific?”, and (4) "Do different exploratory procedures yield different information about the material properties?". Regarding these questions, overall, the multiple dimensions extracted by the materials and the adjectives were in line with literature. Thus, I found four softness dimensions: Deformability, Fluidity, Granularity and Surface softness (Cavdan et al., 2021; Dövencioğlu et al., 2022). In Experiment 1, I presented participants with either names, photographs, or videos of everyday materials and asked them to rate these based on 23 softness-related adjectives. Hence, I hypothesized that (1) mechanical cues will reveal additional information about the material properties, in other words, it was predicted that the ratings in the video condition would be higher than in the other two conditions (photo condition and word condition), (2) the mechanical adjectives (elastic, gooey, deformable, etc.) would have significantly higher ratings in video condition than in the other two conditions, and (3) there would be differences that are specific to the given dimension in the ratings of adjectives between video condition and word and photo conditions, such as for the materials spread in “Fluidity” dimension, I expected the adjective “Sticky” to yield a significantly higher rating in video condition compared to photo or word condition.

Our results revealed that the main effect of the condition was not statistically significant, therefore, I can say that overall, our first hypothesis was not supported. Yet, I expected to see an interaction effect, which means that I anticipated seeing significantly different ratings between conditions depending on the material and adjective in question. For instance, the rating in the video condition of honey would be higher for the adjective “slimy” but not for the “deformable”. The second hypothesis was supported by the data. Rating differences were found between photo-video and video-word conditions of mechanical adjectives for certain materials. I also observed rating differences between photo-word and video-word conditions of adjectives that reflect the optic properties of materials, such as glossy and moisturous. I will further discuss these results in the next subsection. For our last hypothesis in the first study, I observed that there were rating differences between the conditions of adjectives based on dimensionality. Further, I found that these differences were associated with the relationship between adjectives and the given dimension, which means that if the adjective is descriptive of the dimension, the hypothesized differences between the experimental conditions were more likely to be observed. Therefore, I can say that our third hypothesis is partly supported.

In Experiment 2 and 3, participants viewed two different videos of 8 materials, one contains a congruent EP, and the other includes an incongruent EP, and the task was to rate the materials based on 12 softness-related adjectives. I hypothesized that the EP correlated with the dimension of the rated material would generate higher ratings for the adjectives that are related to the given dimension than the EP that is not associated with this dimension. The findings of Experiment 2 did not support our hypothesis. Thus, to see whether this was caused by our EP selection, I carried out a second study in which I kept incongruent EP (stirring) constant across all materials. The results indicated that the EPs that were shown in the videos play a crucial role in the perception of material properties, thus, our hypothesis was supported. The congruent EPs revealed much information regarding the material properties compared to the incongruent EPs, and these differences were dependent on the association between material and adjective. For instance, the adjective “sticky” revealed a higher rating in the congruent condition of shower gel. Because shower gel is a fluid material and the adjective “sticky” is associated with viscous properties, this is in line with our hypothesis. These findings related to Experiment 2 and 3 will be discussed in the following subsections.

4.2. Discussion of the Results of Experiment 1

In the first part of the thesis, I carried out a study that aims to investigate whether mechanical cues will have an advantage on the perception of material properties over optic cues and prior knowledge. As the results suggested, I observed significant rating differences specific to the material-adjective pairs. Furthermore, the results of this study indicated that there were dimension-specific differences between the conditions. From here on, I will discuss the results that were based on dimensionality.

Here, similar to Cavdan et al. (2021)'s study, I have three types of rating differences. The first group’s ratings were significantly different between the video condition and the photo condition. This outcome is contrary to that of Cavdan et al. (2021)'s study who claimed that mechanical and static visual spaces highly corresponded. Instead, this study supports evidence from Wijntjes et al. (2019), where the videos of the material revealed higher ratings compared to the photographs of them, except for adjective “rigid” in the “Deformability” dimension which had a higher rating in the photo condition. "Fluidity” materials were rated higher for "elastic, slimy, soft, and sticky" in video condition, and for the "Granularity" materials, "elastic, gooey, scaly, silky, slippery, and soft" yielded higher ratings in the video condition than in the photo condition. As can be seen, the adjectives that revealed rating differences between the two conditions inform us about the mechanical properties of the materials in the study. According to Cavdan et al. (2021), static images can convey information about material properties, but they can do this through associations. For instance, the shape of the material gives cues about its properties, yet when the material in the photo looks unfamiliar to the observer, it might become harder to form associations and recall the related information. Even though Xiao et al. (2016) contended that still images can convey accurate information about material properties, these can be misleading, and the videos of the materials can reveal much accurate information through mechanical cues (Bouman et al., 2013; Wijntjes et al., 2019).

The second type of difference was between the word and photo conditions. For the "Deformability" and "Surface softness" materials, "glossy" yielded higher ratings in the photo conditions compared to the word condition. Because the properties of glossiness are dependent on visual information (Baumgartner et al., 2013), I anticipated observing higher ratings in the photo condition, and it is in line with our hypothesis. In addition, in these two dimensions, "gooey" revealed higher ratings in the word condition. In the “Fluidity” dimension, “silky” and in the “Granularity” dimension,” powdery” yielded higher ratings in the word condition. Although prior experience with the materials in our surroundings affects our perception of them, it also helps us to form representations or store information about the material properties (Abdel Rahman & Sommer, 2008; Metzger & Drewing, 2019; Urgen & Boyacı, 2021; Witzel et al, 2011; Zoeller et al., 2019). Therefore, calling or seeing the name of material might prime the conceptual knowledge about it (Abdel Rahman & Sommer, 2008; Balota & Coane, 2008; Kumar, 2021) which can in turn affect the judgments of observers. However, this judgment might be misleading because it is subjective and also priming one concept might prime other concepts and it can interfere with the recall of the related information. It may be the case therefore that when the participants saw the name of the materials on the screen, the recalled information might be different from what the materials looked like. It can be suggested that this discrepancy can result in rating differences between the two conditions. As Balcetis and Dunning (2010) demonstrated in their study, the internal goals and desires of individuals might lead to biased perceptions. Therefore, it can result in ambiguous or misleading perceptions (Scocchia et al., 2013) to base the haptic judgments only on prior knowledge.

In the third group, I observed rating differences between the video and word conditions. In the “Deformability” dimension, “delicate and elastic” revealed higher ratings and “sticky” revealed lower ratings in the video condition. In the “Fluidity” dimension, “elastic, gelatinous, glossy, gooey, moisturous, slimy, and soft” yielded higher ratings in the video condition than in the word condition. In the “Granularity” dimension, “granular and powdery” resulted in getting higher ratings in the word condition. Finally, in the “Surface softness” dimension, “glossy” has higher ratings in the video condition compared to the word condition.

As Cavdan et al. (2021) suggested, over time prior knowledge about the materials might form a concept regarding their visual, haptic, and semantic qualities and properties based on the experience itself (Alley et al., 2020). Also, even though I only explored a material visually, I can still judge its haptic properties based merely on visual input. Nevertheless, this visual information itself might not be enough to judge the properties of materials, especially when they are not often encountered in the environment (Abdel Rahman & Sommer, 2008; Witzel et al., 2011; Zoeller et al., 2019). Although I tried to use everyday materials in the study, individual experiences might differ. Moreover, how people interacted with these materials can diverge from one another. On the other hand, momentary visual information tells us another story. Mechanical visual cues manifest information about the materials and help observers to evaluate the properties of the materials based on received information as close as the haptic experience of those materials (Bouman et al., 2013; Cavdan et al., 2021; Wijntjes et al., 2019; Xiao et al., 2016). Moreover, as Yokosaka et al. (2018) showed, even though they are not precise in their estimations, people are quite good at extracting tactile information about the properties of materials from videos in which a hand is exploring the material. Thus, I can conclude that our results partly supported our hypothesis suggesting that videos of materials can provide more accurate information about their properties. Additionally, I observed that adjectives manifesting mechanical properties (such as gooey and sticky) of materials yielded higher ratings in the video condition than in the word condition for the fluid/viscous materials, as I hypothesized. I can suggest that information about the mechanical properties of materials can benefit from the videos because shape associations might be insufficient for providing the necessary information about the viscosity of materials. These results further support the findings of Cavdan et al. (2021).

Finally, I noticed that our last hypothesis was supported by the "Fluidity" and "Granularity" dimensions between the video and word conditions. I observed additional significant differences, yet they were not dimension specific. This rather contradictory result may be due to the fact that they might be either related to the ambiguity of materials in the photographs or their conceptual knowledge (prior experience of participants with those materials).

4.3. Discussion of the Results of Experiment 2 and 3

In the second part of the thesis, I investigated how individuals interact with a material alters its perception and how they describe its softness. Based on our first study and its findings, I carried out research in which an Exploratory Procedure (EP) is applied to a material. One of the EPs was congruent with the material's dimension and the other was incongruent. The EP selection was based on Dövencioğlu et al. (2022)'s study. Here, Experiment 2 set out with the aim of assessing whether the ratings of the participants for the adjectives that are attributed to the same material dimension would be higher (or lower) when they observed the video with a congruent EP than when the EP was incongruent. Contrary to expectations, a different pattern was observed. There were no significant differences for the deformable materials. Confirming to our hypothesis, in the "fluidity" dimension, significant rating differences between the conditions of "sticky" for "shower gel" were found. The other significant difference was in the "sandy" for "hair conditioner". This finding was unexpected because we did not anticipate that being sandy is a property that might be attributed to viscous materials. Moreover, in the "granularity" dimension, "kinetic sand" depicted a pattern that fits in both the viscous and deformable properties of materials. The emergence of the viscoelastic properties might be observed because the participants were unfamiliar with the object. Thus, their prior knowledge about its properties might be limited and it was most probably based on the activation of similar objects and properties. There was one unexpected result in this dimension, which was between the conditions of "elastic" for "flour". This surprising result might be due to the fact that EPs in both conditions changed participants' perception. Lastly, the only significant difference for the "Surface softness" dimension was between the conditions of "malleable" for "cotton", in favor of the incongruent condition.

In light of the findings of Dövencioğlu et al. (2022), I can suggest that EP selection has an effect on the perception of material properties. Moreover, as Atkinson et al. (2013) showed, lighting and manipulation techniques that were used to interact with materials can affect the information that one gets from the videos. Nevertheless, in the current study, the EPs that I chose are related to certain material properties. Stroking is associated with surface softness properties, pulling is associated with viscous properties, run-through and rotating are related to granular dimension, and pressure is related to the deformable dimension (Dövencioğlu et al., 2022). The association of each chosen EP with a certain dimension might play a confounding role in the study because no matter what the EP is, it reveals specific information about the material properties. Therefore, it is not surprising that the results are inconsistent with our hypothesis. Besides, when an observer identifies an object, its kinetic properties are also activated, and prior knowledge might play a role in haptic judgments (Alley et al., 2020; Cavdan et al., 2021). Thus, taking into consideration this, I tried to prevent interference by instructing the participants that they should be as quick as possible in their evaluations. Yet still, some of the participants might spend a lot of time on certain materials and this might have influenced their evaluations.

To investigate our hypothesis further, Experiment 3 was conducted with the same design but with changes in EP and material selection. Yet, because the incongruent EP ("stirring") can reveal viscous properties easily, I did not hypothesize to find any significant differences for the fluid materials. To our surprise, a significant difference between the conditions of "gooey" for "honey" was found. Yet, still, it might have resulted from the fact that pulling might be more informative than stirring when it comes to judging gooeyness. Further, "sponge", which was one of the deformable materials revealed results that were in line with our hypothesis. Also, "wool balls" which were the other deformable material yielded similar results and additionally, two unexpected results for "slippery and silky" were observed. In the "granularity" dimension, kinetic sand manifested its deformable properties, yet it did not demonstrate viscous properties. This finding was not a surprise since I did not predict to observe a significant difference for the fluid materials due to the EP selection. Additionally, “sugar” reflected viscous properties for “slippery and sticky”, and it also revealed a significant difference between the conditions of “velvety”. Lastly, “velvet and fur” yielded consistent results with our hypothesis. There were significant differences between the conditions of “silky and velvety” for “fur”. I also found a significant difference in “powdery” for “fur”. This finding was surprising since “fur” does not exhibit any granular properties, nor the incongruent EP was associated with the “granularity” dimension.

As Dövencioğlu et al. (2022) demonstrated that each EP is correlated with certain material properties and here, in this thesis, I was also able to illustrate the same pattern. What is more, the study enabled us to observe that I can also manipulate the observers' perception while judging materials simply by changing how an EP interacts with that material. As can be seen from the findings, the unanticipated results were mostly related to the viscous properties of materials. Even though Dövencioğlu et al. (2022) did not find any significant correlation between stirring and a certain dimension, there might be an association between stirring and viscosity. Due to this association, I might have observed significantly higher ratings for the adjectives manifesting viscous properties in incongruent conditions (stirring). The only three findings that did not correlate with this pattern were between the conditions of “velvety” for “honey and sugar” and “powdery” for “fur”. Velvety yielded higher ratings in the incongruent condition of “honey and sugar” while “powdery” had higher ratings in the congruent condition of “fur”. For the first two findings, it is possible that because stirring includes continuous touch with the material and its surface, it has a resemblance to stroking in revealing surface softness properties. This also might be a reason that I did not observe all the expected differences for the "surface softness" dimension. Moreover, Dövencioğlu et al. (2022) did not find any association between stirring and any dimension because participants stirred very rarely compared to other EPs. They did not have enough data, hence, stirring did not come up as uniquely associated with a dimension. It includes mechanical motion and also continuous contact with the explored material.

4.4. Limitations

The first limitation of this study was that the materials in the experiments were chosen from among the everyday materials because it was not possible to come up with a large number of ambiguous or unknown materials. Thus, I could not control participants’ prior knowledge regarding the materials strictly. And I could not ensure how much their experience with the materials differs from one another. Since this might play a confounding role in the study, it might have affected the results to a certain extent. The second limitation was that Experiment 1 took approximately one hour for each participant. The length of Experiment 1 might have tired the participants. After a certain point, they might have lost focus which in turn might have affected their judgments.

4.5. Future Research

First of all, in future research surprising materials can be used. I believe that to observe the effect of prior knowledge and visual cues, known and unknown materials can be used as stimuli and compared to each other. Hence, one can reach a clearer conclusion about whether people benefit from prior knowledge, or they base their judgments on momentarily received visual cues. As mentioned in the first limitation, future research can also control the level of knowledge participants have regarding the materials. A preliminary study, they can be asked if they know the materials and how often they interact with them. This might help us to match the participants and assign them randomly to different conditions. Therefore, participants in each condition will have matched level of prior knowledge, and this eliminates any confounding role that the level of knowledge has. Lastly, experiments with longer durations might be divided into parts. Thus, participants can relax and focus on experiment better.

4.6. Conclusion

To sum up, it was hypothesized that mechanical cues would manifest themselves better in video conditions since the mechanical properties can be seen better in a video, as compared to photographs and prior knowledge. It was also expected that there would be rating differences between video condition and other two conditions for mechanical adjectives, such as slimy and elastic. Furthermore, it was hypothesized that these differences will manifest themselves based on dimensionality of materials and adjectives. Lastly, it was assumed that Exploratory Procedures (EPs) that are used to interact with materials can manipulate the participants' judgments about the material properties. The results indicated that the first hypothesis was not supported. The ratings of the participants did not differ based on the condition. Yet, the rating differences were observed between the pairs of conditions for optic or mechanical cues, which supported the second hypothesis. The third hypothesis was partly supported by the data. The adjectives that are loaded on a certain dimension were more likely to reveal higher ratings in video condition than in the other two conditions. Lastly, the fourth hypothesis was also partially supported by Experiment 2 and 3. It was observed that the congruent EP might result in higher ratings for the adjectives that were chosen from the same dimension with the material. However, these rating differences might be dependent on the representational capacity of materials and adjectives for the dimension.

To our knowledge, this is one of the first research that compared the role of prior knowledge and visual cues of perceived softness together. Moreover, it is the first research that investigates whether EPs can manipulate the judgments about material properties. Therefore, this thesis paved the way to study the role of EPs in extracting the material properties from videos. With further research, it can contribute to the development in several areas ranging from online shopping to robotics.

REFERENCES

Abdel Rahman, R., & Sommer, W. (2008). Seeing what we know and understand: How knowledge shapes perception. *Psychonomic Bulletin & Review, 15(6),* 1055–1063. https://doi.org/10.3758/PBR.15.6.1055

Aleman, A., van Lee, L., Mantione, M. H. M., Verkoijen, I. G., & de Haan, E. H. F. (2001). Visual imagery without visual experience: Evidence from congenitally totally blind people: *Neuroreport, 12(11),* 2601–2604. https://doi.org/10.1097/00001756-200108080-00061

Alley, L. M., Schmid, A. C., & Doerschner, K. (2020). Expectations affect the perception of material properties. *Journal of Vision, 20(12),* 1. https://doi.org/10.1167/jov.20.12.1

Allport, D. A. (1985). Distributed Memory, Modular Systems and Dysphasia. In S. K. Newman & R. Epstein (ed.), *Current Perspectives in Dysphasia.* Churchill Livingstone.

Atkinson, D., Orzechowski, P., Petreca, B., Bianchi-Berthouze, N., Watkins, P., Baurley, S., ... & Chantler, M. (2013, April). Tactile perceptions of digital textiles: a design research approach. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1669-1678). https://doi.org/10.1145/2470654.2466221

Bach, P., & Schenke, K. C. (2017). Predictive social perception: Towards a unifying framework from action observation to person knowledge. *Social and Personality Psychology Compass, 11(7),* e12312. https://doi.org/10.1111/spc3.12312

Balcetis, E., & Dunning, D. (2010). Wishful Seeing: More Desired Objects Are Seen as Closer. *Psychological Science, 21(1),* 147–152. https://doi.org/10.1177/0956797609356283

Ballesteros, S., & Reales, J. M. (2004). Intact haptic priming in normal aging and Alzheimer's disease: Evidence for dissociable memory systems. *Neuropsychologia, 42(8),* 1063–1070. https://doi.org/10.1016/j.neuropsychologia.2003.12.008

Balota, D. A., & Coane, J. H. (2008). Semantic memory. *Elsevier*

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22(4),* 577–660. https://doi.org/10.1017/S0140525X99002149

Baumgartner, E., Wiebel, C. B., & Gegenfurtner, K. R. (2013). Visual and Haptic Representations of Material Properties. *Multisensory Research, 26(5),* 429–455. https://doi.org/10.1163/22134808-00002429

Bergmann Tiest, W. M., & Kappers, A. M. L. (2006). Analysis of haptic perception of materials by multidimensional scaling and physical measurements of roughness and compressibility. *Acta Psychologica, 121(1),* 1–20. https://doi.org/10.1016/j.actpsy.2005.04.005

Bergmann Tiest, W. M., & Kappers, A. M. L. (2007). Haptic and visual perception of roughness. *Acta Psychologica, 124(2),* 177–189. https://doi.org/10.1016/j.actpsy.2006.03.002

Bliss, J. C., Crane, H. D., Mansfield, P. K., & Townsend, J. T. (1966). Information available in brief tactile presentations. *Perception & Psychophysics, 1(4),* 273–283. https://doi.org/10.3758/BF03207391

Bouman, K. L., Xiao, B., Battaglia, P., & Freeman, W. T. (2013). Estimating the Material Properties of Fabric from Video. *2013 IEEE International Conference on Computer Vision,* 1984–1991. https://doi.org/10.1109/ICCV.2013.455

Cavdan, M., Doerschner, K., & Drewing, K. (2019). The many dimensions underlying perceived softness: How exploratory procedures are influenced by material and the perceptual task. *2019 IEEE World Haptics Conference (WHC),* 437–442. https://doi.org/10.1109/WHC.2019.8816088

Cavdan, M., Drewing, K., & Doerschner, K. (2021). The look and feel of soft are similar across different softness dimensions. *Journal of Vision, 21(10),* 20. https://doi.org/10.1167/jov.21.10.20

Damasio, A. R. (1989). The Brain Binds Entities and Events by Multiregional Activation from Convergence Zones. *Neural Computation, 1(1),* 123–132. https://doi.org/10.1162/neco.1989.1.1.123

Di Luca, M. (Ed.). (2014). Multisensory Softness. *Springer London.* https://doi.org/10.1007/978-1-4471-6533-0

Doerschner, K., Fleming, R. W., Yilmaz, O., Schrater, P. R., Hartung, B., & Kersten, D. (2011). Visual Motion and the Perception of Surface Material. *Current Biology, 21(23),* 2010–2016. https://doi.org/10.1016/j.cub.2011.10.036

Dövencioğlu, D. N., Doerschner, K. & Drewing, K. (2018). Aspects of Material Softness in Active Touch. 41st European Conference on Visual Perception (ECVP) 2018 Trieste. *Perception, 48(1_suppl),* (pp. 144). https://doi.org/10.1177/0301006618824879

Dövencioğlu, D. N., Doerschner, K. & Drewing, K. (2019, September). Material Softness Dimension in Active Touch. 42nd European Conference on Visual Perception (ECVP) 2019 Leuven. (2019). *Perception, 48(2_suppl),* (pp. 205). https://doi.org/10.1177/0301006619863862

Dövencioğlu, D. N., Üstün, F. S., Doerschner, K., & Drewing, K. (2022). Hand explorations are determined by the characteristics of the perceptual space of real-world materials from silk to sand. *Scientific Reports*, *12*(1), 1-12. https://doi.org/10.1038/s41598-022-18901-6

Drewing, K., Weyel, C., Celebi, H., & Kaya, D. (2017). Feeling and feelings: Affective and perceptual dimensions of touched materials and their connection. *2017 IEEE World Haptics Conference (WHC),* 25–30. https://doi.org/10.1109/WHC.2017.7989851

Easton, R. D., Srinivas, K., & Greene, A. J. (1997). Do vision and haptics share common representations? Implicit and explicit memory within and between modalities. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23(1),* 153–163. https://doi.org/10.1037/0278-7393.23.1.153

Ferreira, C. D., Gadelha, M. J. N., Fonsêca, É. K. G. da, Silva, J. S. C. da, Torro, N., & Fernández-Calvo, B. (2019). Long-term memory of haptic and visual information in older adults. *Aging, Neuropsychology, and Cognition, 28(1),* 65–77. https://doi.org/10.1080/13825585.2019.1710450

Friston, K. (2005). A theory of cortical responses. *Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1456),* 815–836. https://doi.org/10.1098/rstb.2005.1622

Friston, K. (2010). The free-energy principle: A unified brain theory? *Nature Reviews Neuroscience, 11(2),* 127–138. https://doi.org/10.1038/nrn2787

Friston, K., Kilner, J., & Harrison, L. (2006). A free energy principle for the brain. *Journal of Physiology-Paris, 100(1–3),* 70–87. https://doi.org/10.1016/j.jphysparis.2006.10.001

Gallace, A., & Spence, C. (2008). The cognitive and neural correlates of "tactile consciousness": A multisensory perspective. *Consciousness and Cognition, 17(1),* 370–407. https://doi.org/10.1016/j.concog.2007.01.005

Gallace, A., & Spence, C. (2009). The cognitive and neural correlates of tactile memory. *Psychological Bulletin, 135(3),* 380–406. https://doi.org/10.1037/a0015325

Gauthier, I., James, T. W., Curby, K. M., & Tarr, M. J. (2003). The Influence of Conceptual Knowledge on Visual Discrimination. *Cognitive Neuropsychology, 20(3–6),* 507–523. https://doi.org/10.1080/02643290244000275

Gibson, J. J. (1962). Observations on active touch. *Psychological Review, 69(6),* 477–491. https://doi.org/10.1037/h0046962

Gilbert, C. D., & Li, W. (2013). Top-down influences on visual processing. *Nature Reviews Neuroscience, 14(5),* 350–363. https://doi.org/10.1038/nrn3476

Gilson, E. Q., & Baddeley, A. D. (1969). Tactile Short-Term Memory. *Quarterly Journal of Experimental Psychology, 21(2),* 180–184. https://doi.org/10.1080/14640746908400211

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. *Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education*.

Goldstein, E. B. (2010). Sensation and perception. *Cengage Learning*.

Goodwin, A.W. & Wheat, H.E. (2008). Physiological Mechanisms of Receptor System. In Jütte, R. (Auth.), Grunwald, M. (Ed.). (2008). *Human haptic perception: Basics and applications.* Birkhäuser. https://doi.org/10.1007/978-3-7643-7612-3

Guest, S., Dessirier, J. M., Mehrabyan, A., McGlone, F., Essick, G., Gescheider, G., ... & Blot, K. (2011). The development and validation of sensory and emotional scales of touch perception. *Attention, Perception, & Psychophysics*, *73*(2), 531-550. https://doi.org/10.3758/s13414-010-0037-y

Hansen, T., Olkkonen, M., Walter, S., & Gegenfurtner, K. R. (2006). Memory modulates color appearance. *Nature Neuroscience, 9(11),* 1367–1368. https://doi.org/10.1038/nn1794

Hollins, M., Faldowski, R., Rao, S., & Young, F. (1993). Perceptual dimensions of tactile surface texture: A multidimensional scaling analysis. *Perception & Psychophysics, 54(6),* 697–705. https://doi.org/10.3758/BF03211795

Hutmacher, F., & Kuhbandner, C. (2018). Long-Term Memory for Haptically Explored Objects: Fidelity, Durability, Incidental Encoding, and Cross-Modal Transfer. *Psychological Science, 29(12),* 2031–2038. https://doi.org/10.1177/0956797618803644

Kaim, L., & Drewing, K. (2011). Exploratory Strategies in Haptic Softness Discrimination Are Tuned to Achieve High Levels of Task Performance. *IEEE Transactions on Haptics, 4(4),* 242–252. https://doi.org/10.1109/TOH.2011.19

Kersten, D., & Mamassian, P. (2009). Ideal observer theory. *Encyclopedia of neuroscience, 5,* 89-95.

Kersten, D., Mamassian, P., & Yuille, A. (2004). Object Perception as Bayesian Inference. *Annual Review of Psychology, 55(1),* 271–304. https://doi.org/10.1146/annurev.psych.55.090902.142005

Kersten, D., & Yuille, A. (2003). Bayesian models of object perception. *Current Opinion in Neurobiology, 13(2),* 150–158. https://doi.org/10.1016/S0959-4388(03)00042-4

Kilner, J. M., Friston, K. J., & Frith, C. D. (2007a). The mirror-neuron system: A Bayesian perspective. *NeuroReport, 18(6),* 619–623. https://doi.org/10.1097/WNR.0b013e3281139ed0

Kilner, J. M., Friston, K. J., & Frith, C. D. (2007b). Predictive coding: An account of the mirror neuron system. *Cognitive Processing, 8(3),* 159–166. https://doi.org/10.1007/s10339-007-0170-2

Kiphart, M. J., Auday, B. C., & Cross, H. A. (1988). Short-Term Haptic Memory for Three-Dimensional Objects. *Perceptual and Motor Skills, 66(1),* 79–91. https://doi.org/10.2466/pms.1988.66.1.79

Klatzky, R. L., Lederman, S. J., & Metzger, V. A. (1985). Identifying objects by touch: An “expert system.”. *Perception & Psychophysics, 37(4),* 299–302. https://doi.org/10.3758/BF03211351

Kumar, A. A. (2021). Semantic memory: A review of methods, models, and current challenges. *Psychonomic Bulletin & Review, 28(1),* 40–80. https://doi.org/10.3758/s13423-020-01792-x

Kveraga, K., Ghuman, A. S., & Bar, M. (2007). Top-down predictions in the cognitive brain. *Brain and Cognition, 65(2),* 145–168. https://doi.org/10.1016/j.bandc.2007.06.007

Lacey, S., & Campbell, C. (2006). Mental representation in visual/haptic crossmodal memory: Evidence from interference effects. *Quarterly Journal of Experimental Psychology, 59(2),* 361–376. https://doi.org/10.1080/17470210500173232

Lacey, S., Campbell, C., & Sathian, K. (2007). Vision and Touch: Multiple or Multisensory Representations of Objects? *Perception, 36(10),* 1513–1521. https://doi.org/10.1068/p5850

Lederman, S. J., & Klatzky, R. L. (1987). Hand movements: A window into haptic object recognition. *Cognitive Psychology, 19(3),* 342–368. https://doi.org/10.1016/0010-0285(87)90008-9

Lezkan, A., & Drewing, K. (2015). Predictive and sensory signals systematically lower peak forces in the exploration of softer objects. *2015 IEEE World Haptics Conference (WHC),* 69–74. https://doi.org/10.1109/WHC.2015.7177693

Liu, J., & Song, A. (2008). Discrimination and Memory Experiments on Haptic Perception of Softness. *Perceptual and Motor Skills*, *106(1),* 295–306. https://doi.org/10.2466/pms.106.1.295-306

Manning, S. K. (1978). The Effects of Interpolated Interference on Tactual and Visual Short-Term Memory. *The American Journal of Psychology, 91(3),* 445. https://doi.org/10.2307/1421691

Metzger, A., & Drewing, K. (2019). Memory influences haptic perception of softness. *Scientific Reports, 9(1),* 14383. https://doi.org/10.1038/s41598-019-50835-4

Miles, C. (1996). Tactile Short-term Memory Revisited. *Memory, 4(6),* 655–668. https://doi.org/10.1080/741940995

Millar, S. (1999). Memory in touch. *Psicothema, 11(4),* 747-767.

Millar, S., & Al-Attar, Z. (2004). External and body-centered frames of reference in spatial memory: Evidence from touch. *Perception & Psychophysics, 66(1),* 51–59. https://doi.org/10.3758/BF03194860

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological review, 63(2),* 81. https://doi.org/10.1037/h0043158

Murray, D. J., Ward, R., & Hockley, W. E. (1975). Tactile Short-Term Memory in Relation to the Two-Point Threshold. *Quarterly Journal of Experimental Psychology, 27(2),* 303–312. https://doi.org/10.1080/14640747508400489

Norman, J. F., Norman, H. F., Clayton, A. M., & Lianekhammy, J., Zielke, G. (2004). The visual and haptic perception of natural object shape. *Perception & Psychophysics, 66 (2),* 342–351. https://doi.org/10.3758/BF03194883

Okamoto, S., Nagano, H., & Yamada, Y. (2013). Psychophysical Dimensions of Tactile Perception of Textures. *IEEE Transactions on Haptics, 6(1),* 81–93. https://doi.org/10.1109/TOH.2012.32

Olkkonen, M., & Allred, S. R. (2014). Short-Term Memory Affects Color Perception in Context. *PLoS ONE, 9(1),* e86488. https://doi.org/10.1371/journal.pone.0086488

Osgood, C. E. (1952). The nature and measurement of meaning. *Psychological Bulletin, 49(3)*, 197–237. https://doi.org/10.1037/h0055737

Paivio, A. (1986). Mental representations: A dual-coding approach*. New York: Oxford University Press.*

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience, 8(12),* 976–987. https://doi.org/10.1038/nrn2277

Pensky, A. E. C., Johnson, K. A., Haag, S., & Homa, D. (2008). Delayed memory for visual-haptic exploration of familiar objects. *Psychonomic Bulletin & Review, 15(3),* 574–580. https://doi.org/10.3758/PBR.15.3.574

Picard, D. (2006). Partial perceptual equivalence between vision and touch for texture information. *Acta Psychologica, 121(3),* 227–248. https://doi.org/10.1016/j.actpsy.2005.06.001

Pinna, B., & Skdilters, J. (2010). Perceptual semantics: A three-level approach. *2010 10th International Conference on Intelligent Systems Design and Applications,* 772–777. https://doi.org/10.1109/ISDA.2010.5687171

R Core Team (2018). R: A Language and environment for statistical computing. [Computer software]. Retrieved from https://cran.r-project.org/

Schmid, A. C., & Doerschner, K. (2018). Shatter and splatter: The contribution of mechanical and optical properties to the perception of soft and hard breaking materials. *Journal of Vision, 18(1),* 14. https://doi.org/10.1167/18.1.14

Scocchia, L., Valsecchi, M., & Triesch, J. (2014). Top-down influences on ambiguous perception: The role of stable and transient states of the observer. *Frontiers in Human Neuroscience, 8*. https://doi.org/10.3389/fnhum.2014.00979

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs: General and Applied*, *74(11),* 1–29. https://doi.org/10.1037/h0093759

Sullivan, E. V., & Turvey, M. T. (1972). Short-term Retention of Tactile Stimulation. *Quarterly Journal of Experimental Psychology, 24(3),* 253–261. https://doi.org/10.1080/14640747208400278

Summerfield, C., & de Lange, F. P. (2014). Expectation in perceptual decision making: Neural and computational mechanisms. *Nature Reviews Neuroscience*, *15(11),* 745–756. https://doi.org/10.1038/nrn3838

Tanaka, J., Weiskopf, D., & Williams, P. (2001). The role of color in high-level vision. *Trends in Cognitive Sciences*, *5(5),* 211–215. https://doi.org/10.1016/S1364-6613(00)01626-0

The jamovi project (2019). *jamovi*. (Version 1.0) [Computer Software]. Retrieved from https://www.jamovi.org.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. Cambridge, MA: Academic Press.

Tulving, E., & Pearlstone, Z. (1966). Availability Versus Accessibility of Information in Memory for Words. *Journal Of Verbal Learning and Verbal Behavior, 5(4),* 381-391. https://doi.org/10.1016/S0022-5371(66)80048-8

Urgen, B. A., & Saygin, A. P. (2020). Predictive processing account of action perception: Evidence from effective connectivity in the action observation network. *Cortex, 128,* 132–142. https://doi.org/10.1016/j.cortex.2020.03.014

Urgen, B. M., & Boyaci, H. (2021). Unmet expectations delay sensory processes. *Vision Research*, *181*, 1-9. https://doi.org/10.1016/j.visres.2020.12.004

Watkins, M. J., & Watkins, O. C. (1974). A tactile suffix effect. *Memory & Cognition, 2(1),* 176–180. https://doi.org/10.3758/BF03197511

Wendt, G., Faul, F., Ekroll, V., & Mausfeld, R. (2010). Disparity, motion, and color information improve gloss constancy performance. *Journal of Vision, 10(9),* 7–7. https://doi.org/10.1167/10.9.7

Wijntjes, M. W. A., Xiao, B., & Volcic, R. (2019). Visual communication of how fabrics feel. *Journal of Vision, 19(2),* 4. https://doi.org/10.1167/19.2.4

Witzel, C., Valkova, H., Hansen, T., & Gegenfurtner, K. R. (2011). Object Knowledge Modulates Colour Appearance. *I-Perception, 2(1),* 13–49. https://doi.org/10.1068/i0396

Wolfe, H. K. (1898). Some effects of size on judgments of weight. *Psychological Review, 5(1),* 25–54. https://doi.org/10.1037/h0073342

Xiao, B., Bi, W., Jia, X., Wei, H., & Adelson, E. H. (2016). Can you see what you feel? Color and folding properties affect visual–tactile material discrimination of fabrics. *Journal of Vision, 16(3),* 34. https://doi.org/10.1167/16.3.34

Yee, E. (2017). Fluid semantics: Semantic knowledge is experience-based and dynamic. In A. Lahiri & S. Kotzor (Eds.), *The Speech Processing Lexicon* (pp. 236–255). De Gruyter. https://doi.org/10.1515/9783110422658-012

Yee, E., Chrysikou, E. G., Hoffman, E., & Thompson-Schill, S. L. (2013). Manual Experience Shapes Object Representations. *Psychological Science, 24(6),* 909–919. https://doi.org/10.1177/0956797612464658

Yee, E., Huffstetler, S., & Thompson-Schill, S. L. (2011). Function follows form: Activation of shape and function features during object identification. *Journal of Experimental Psychology: General, 140(3),* 348–363. https://doi.org/10.1037/a0022840

Yokosaka, T., Kuroki, S., Watanabe, J., & Nishida, S. (2018). Estimating Tactile Perception by Observing Explorative Hand Motion of Others. *IEEE Transactions on Haptics, 11(2),* 192–203. https://doi.org/10.1109/TOH.2017.2775631

Yoshida, M. (1968). Dimensions of tactual impressions (1). *Japanese Psychological Research, 10(3),* 123-137. https://doi.org/10.4992/psycholres1954.10.123

Zhou, Y.-D., & Fuster, J. M. (1997). Neuronal activity of somatosensory cortex in a cross-modal (visuo-haptic) memory task. *Experimental Brain Research, 116(3),* 551–555. https://doi.org/10.1007/PL00005783

Zoeller, A. C., Lezkan, A., Paulun, V. C., Fleming, R. W., & Drewing, K. (2019). Integration of prior knowledge during haptic exploration depends on information type. *Journal of Vision, 19(4),* 20. https://doi.org/10.1167/19.4.20

APPENDICES

A. APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

Sayı: 28620816 / 147

16 HAZİRAN 2020

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Dr.Öğr.Üyesi Nahide Dicle DÖVENCİOĞLU

Danışmanlığını yaptığınız **Fatma KILIÇ'ın "Anlambilim ve Belleğin Yumuşaklık Algısındaki Rolü"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **147 ODTU 2020** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof.Dr. Mine MISIRLISOY
Başkan

Prof. Dr. Tolga CAN
Üye

Doç.Dr. Pınar KAYGAN
Üye

Dr. Öğr. Üyesi Ali Emre TURGUT
Üye

Dr. Öğr. Üyesi Şerife SEVİNÇ
Üye

Dr. Öğr. Üyesi Müge GÜNDÜZ
Üye

Dr. Öğr. Üyesi Süreyya Özcan KABASAKAL
Üye

B. THE INFORMED CONSENT

Kasım 2021

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Psikoloji Bölümü Yüksek Lisans öğrencisi Fatma Kılıç tarafından Dr. Öğr. Üyesi N. Dicle Dövencioğlu danışmanlığındaki yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı, günlük hayatta kullandığımız materyallerin yumuşaklık algısı ile ilgili bilgi toplamaktır. Kullandığımız bu materyallerin yumuşaklıkları farklı derecelerde ve boyutlardadır. Bu araştırma, farklı uyaran tipi (kelime, fotoğraf ve video) kullanarak bu materyallere atfedilen yumuşaklık derecelerini ve boyutlarını ölçmeyi planlamaktadır.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, sizden bilgisayar ortamında göreceğiniz bazı nesnelerin isimlerini, videolarını veya fotoğraflarını söz konusu materyal özelliğine göre oylamanızı isteyeceğiz (örn. Nesnenin ne kadar yumuşak olduğunu düşünüyorsunuz?). Puanlamalarınız 1 (Hiç) ile 7 (Tamamen) arasında olacak ve fare yardımıyla derecelendirme yapmanızı isteyeceğiz. Araştırma ortalama 90 dakika sürecektir.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Çalışmada sizden kimlik veya kurum belirleyici hiçbir bilgi istenmemektedir. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayımlarda kullanılacaktır.

Katılımınızla ilgili bilmeniz gerekenler:

Araştırma, genel olarak kişisel rahatsızlık verecek sorular veya uygulamalar içermemektedir. Ancak, katılım sırasında herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz araştırmayı yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda çalışmayı uygulayan kişiye çalışmadan çıkmak istediğinizi söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Araştırma sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için yüksek lisans öğrencisi Fatma Kılıç (E-posta:) ya da Psikoloji Bölümü öğretim üyelerinden Dr. Öğr. Üyesi N. Dicle Dövencioğlu (E-posta:) ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.
(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyisim   Tarih   İmza

C. PILOT STUDY

a. Cronbach's alpha results

According to the results in the pilot study, "et gibi (meaty)" and "derimsi (leathery)" yielded Keyser-Olkin-Meyer (KMO) values under 0.40. Consequently, I excluded these two adjectives from the further analyses. (KMO values indicate how suitable our data is for a factor analysis. The cut-off value is 0.50 and the value under the cut-off is interpreted as unacceptable to include in a Principal Component Analysis.) The results of Cronbach's alpha revealed that participants were overall consistent in their ratings. Highest consistency within subjects was for material photos (Mean Cronbach's alpha, a = .85), lowest for names (a = .74). Figure C.1 displays Cronbach's alpha values for each condition.

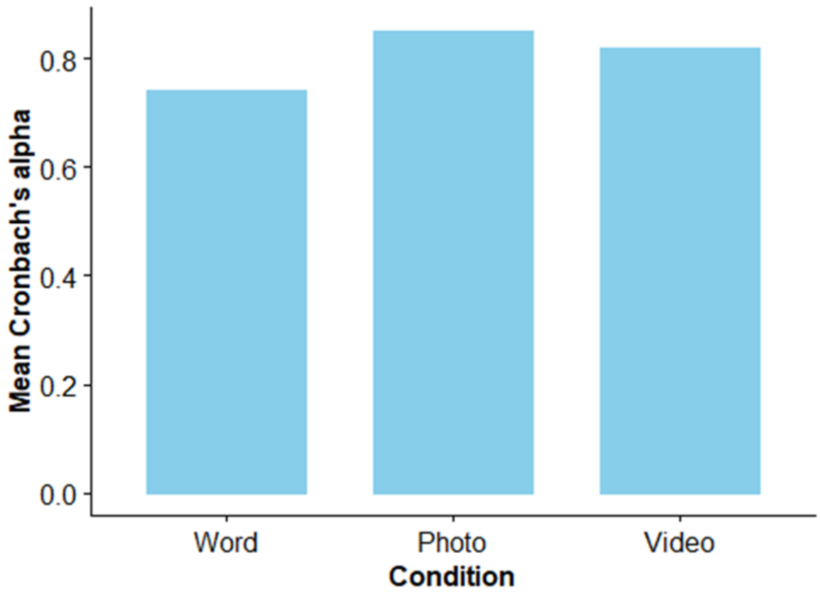


Figure C.1. The mean Cronbach's alpha values for each condition separately.

b. PCA Results

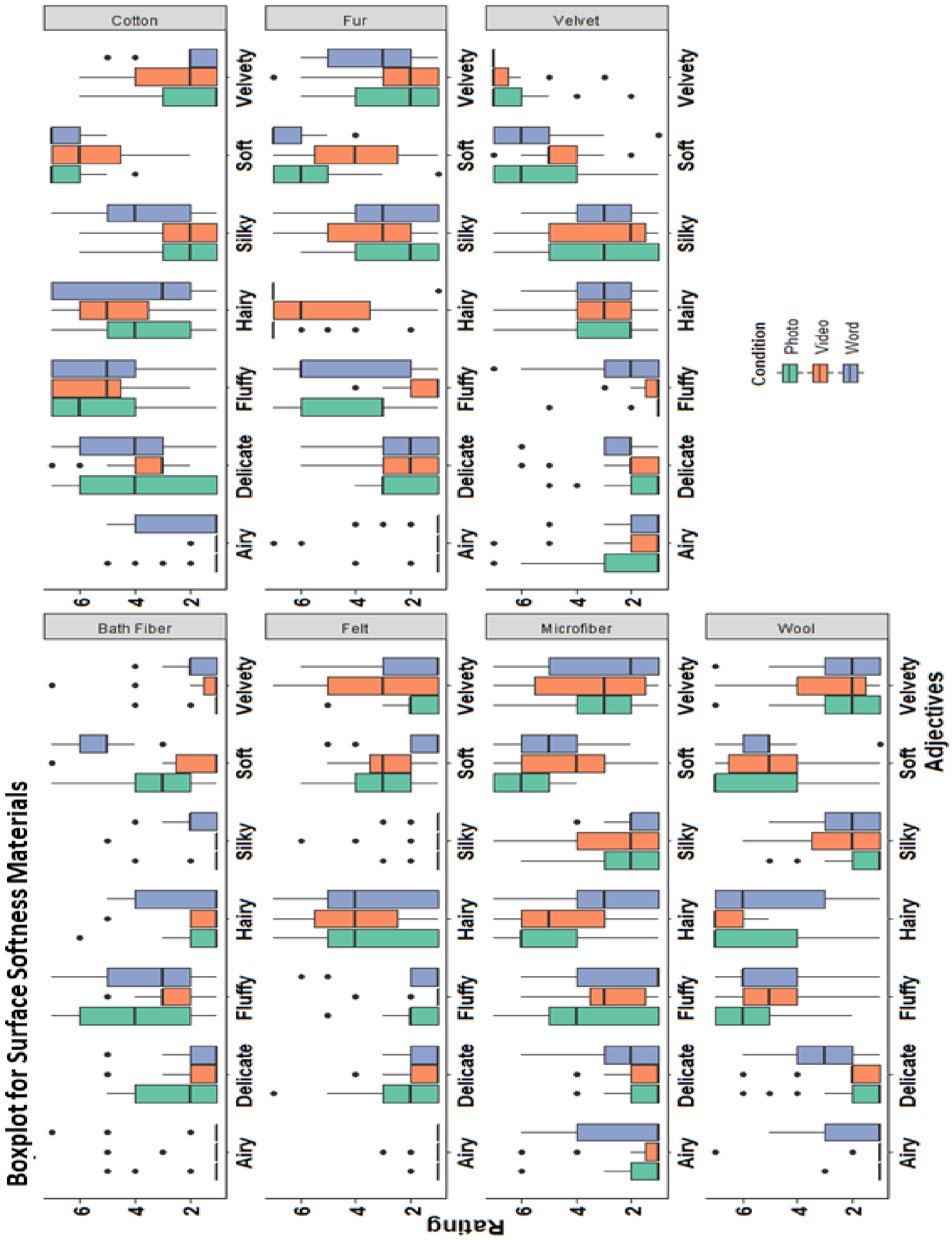


Figure C.2. Boxplots of adjectives and materials that are related to surface softness. Mean ratings given by participants are depicted on the y-axis, and the adjectives that are relevant to that dimension are illustrated on the x-axis.

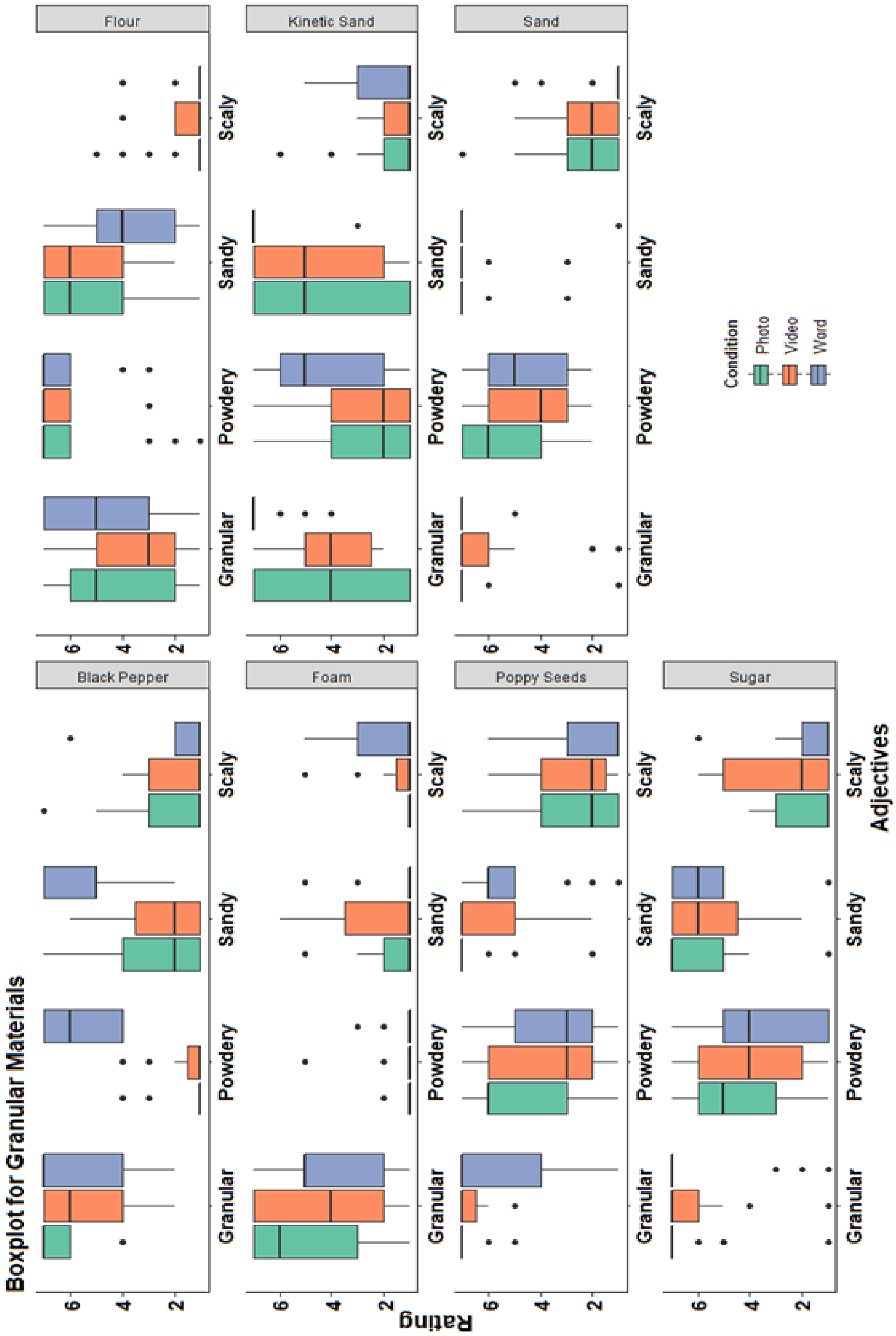


Figure C.3. Boxplots of adjectives and materials that are related to granularity. Mean ratings given by participants are depicted on the y-axis, and the adjectives that are relevant to that dimension are illustrated on the x-axis.

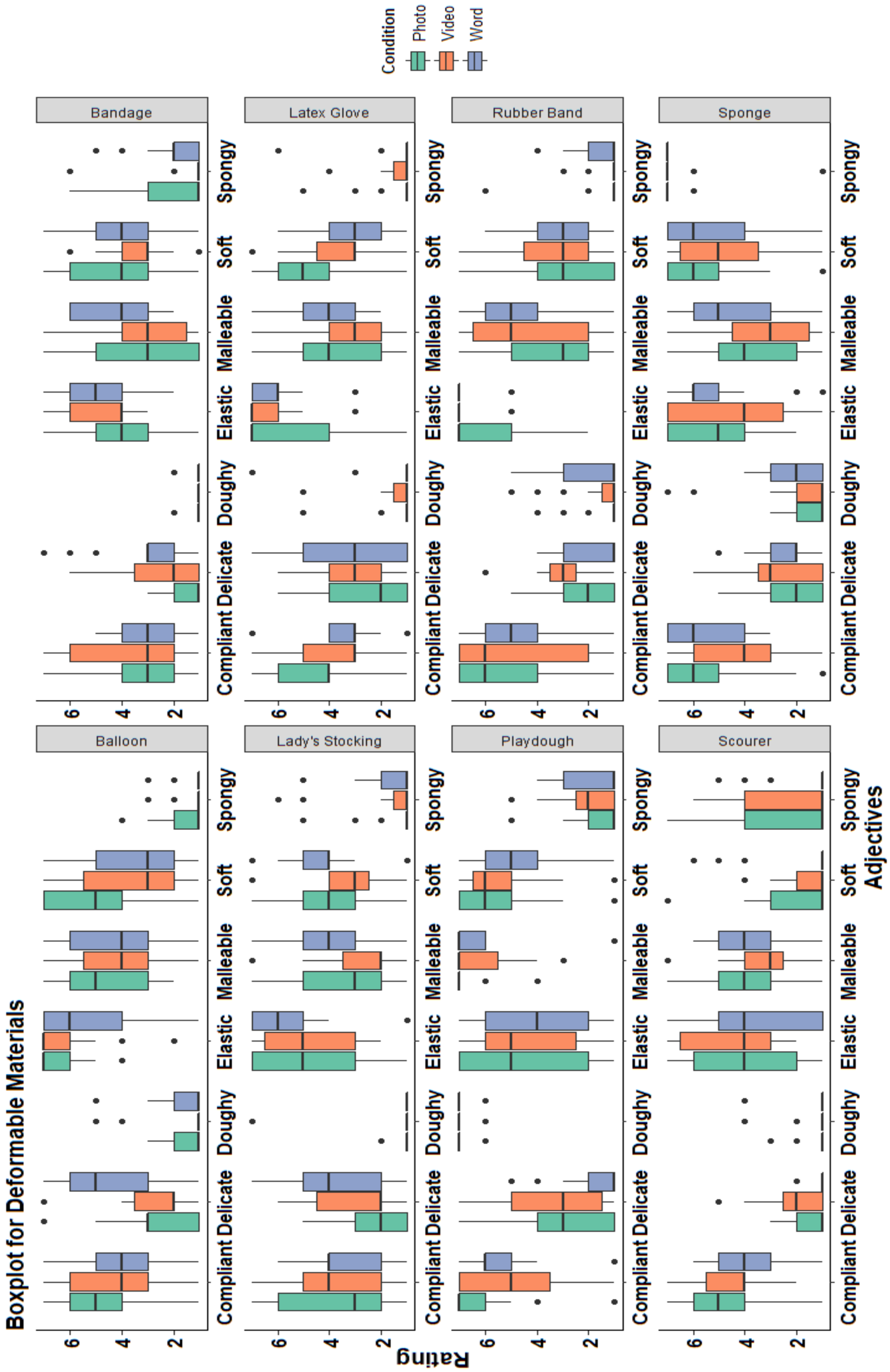


Figure C.4. Boxplots of adjectives and materials that are related to deformability. Mean ratings given by participants are depicted on the y-axis, and the adjectives that are relevant to that dimension are illustrated on the x-axis.

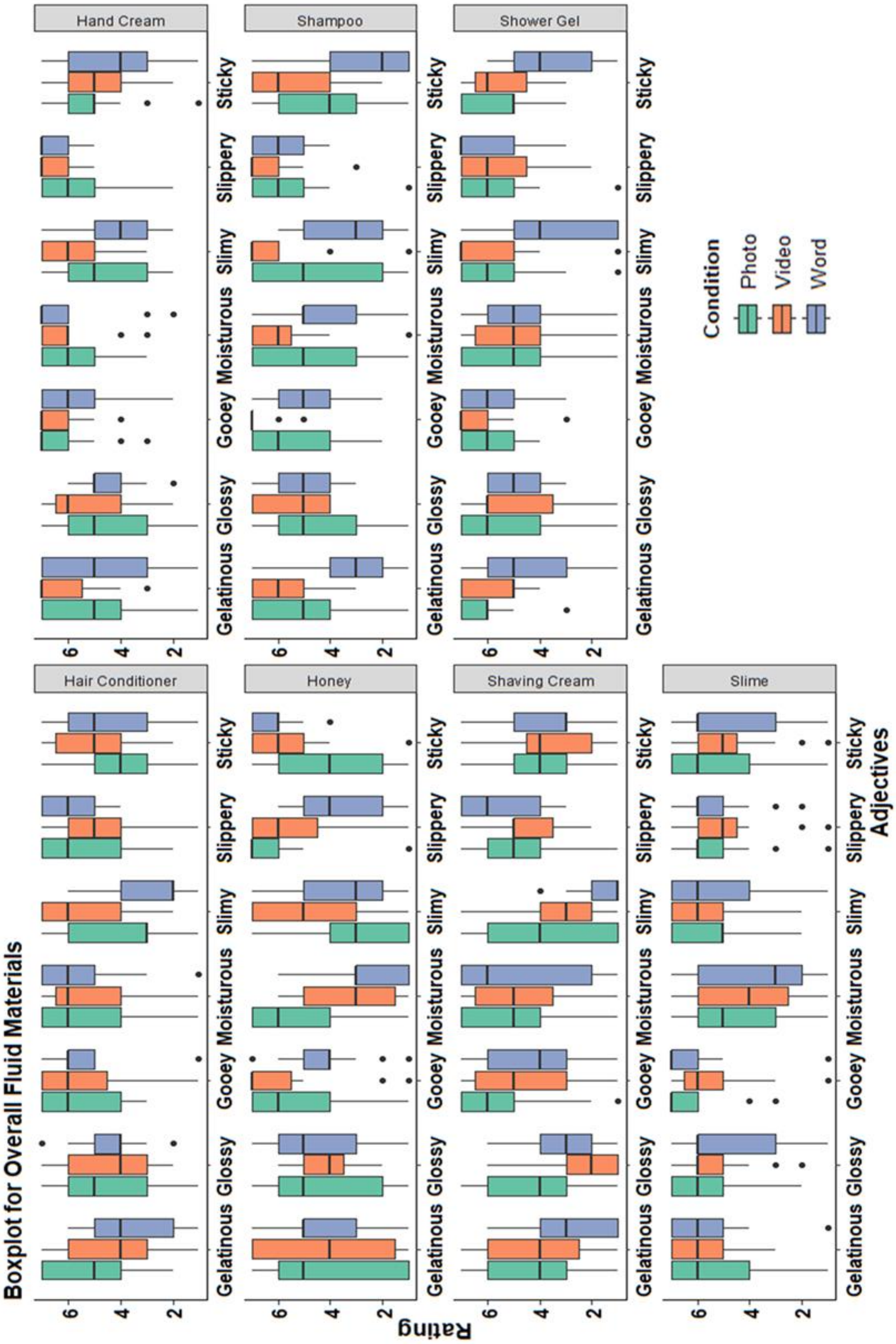


Figure C.5. Boxplots for fluid materials and adjectives. Mean ratings given by participants are depicted on the y-axis, and the adjectives that are relevant to that dimension are illustrated on the x-axis.

D. AN EXAMPLE SCREENSHOT FROM PILOT STUDY

E. PCA TABLES OF EXPERIMENT 1

Table E.1. Component Loadings of Adjectives in Word Condition in Experiment 1

	Component				
	1	2	3	4	Uniqueness
Gooey	0.963				0.0519
Sticky	0.955				0.0734
Gelatinous	0.952				0.0479
Slimy	0.947				0.0560
Slippery	0.932				0.0571
Moisturous	0.921				0.1362
Roughened	-0.709		0.326		0.2956
Glossy	0.677		-0.324		0.3455
Velvety		0.930			0.1246
Silky	0.345	0.915			0.0398
Soft	0.431	0.787		0.410	0.0262
Hairy	-0.475	0.758			0.1406
Delicate		0.703			0.3945
Spongy		0.655		0.601	0.1425
Hard	-0.580	-0.650		-0.404	0.0580
Sandy			0.973		0.0347
Granular			0.970		0.0210
Powdery			0.956		0.0594
Scaly	-0.379		0.871		0.0772
Compliant				0.887	0.1458
Elastic				0.812	0.1582
Rigid			-0.322	-0.721	0.1654
Malleable		0.530		0.711	0.1373

Note. 'varimax' rotation was used

Table E.2. Component Loadings of Adjectives in Photo Condition in Experiment 1

	Component				
	1	2	3	4	Uniqueness
Gooey	0.967				0.0306
Sticky	0.963				0.0353
Gelatinous	0.954				0.0427
Slimy	0.947				0.0547
Moisturous	0.936				0.0558
Slippery	0.886		-0.424		0.0296
Glossy	0.573		-0.441	-0.389	0.3054
Rigid	-0.515			-0.418	0.4750
Hairy		0.905			0.1298
Velvety		0.902			0.1558
Silky		0.875			0.1505
Spongy		0.836			0.1564
Soft	0.527	0.738		0.370	0.0391
Compliant	-0.430	0.574	-0.312		0.3759
Powdery			0.943		0.0728
Sandy			0.940		0.0448
Granular	-0.314		0.834	-0.322	0.0774
Scaly	-0.425		0.742		0.1752
Roughened	-0.416	0.396	0.656		0.2356
Delicate		0.365	-0.398	0.754	0.1234
Malleable	0.320	0.486		0.708	0.1581
Hard	-0.609	-0.404		-0.639	0.0578
Elastic		0.468	-0.402	0.629	0.2242

Note. 'varimax' rotation was used

Table E.3. Component Loadings of Adjectives in Video Condition in Experiment 1

	Component				
	1	2	3	4	Uniqueness
Sticky	0.970				0.0267
Slippery	0.945				0.0338
Gooey	0.945				0.0437
Moisturous	0.943				0.0567
Gelatinous	0.940				0.0287
Slimy	0.937				0.0299
Glossy	0.766				0.2518
Roughened	-0.656		0.349		0.3275
Elastic		0.884			0.0825
Rigid	-0.372	-0.841			0.1325
Compliant	-0.326	0.828			0.1321
Malleable	0.370	0.814			0.1131
Delicate		0.771		0.307	0.2523
Spongy	-0.342	0.768		0.383	0.1362
Hard	-0.510	-0.700		-0.423	0.0697
Soft	0.555	0.628		0.497	0.0505
Sandy			0.975		0.0303
Powdery			0.965		0.0543
Granular			0.897		0.0450
Scaly	-0.370		0.874		0.0741
Velvety		0.320		0.913	0.0496
Silky		-0.302		0.909	0.0207
Hairy	-0.402			0.776	0.1143

Note. 'varimax' rotation was used

Table E.4. Component Loadings of Materials in Word Condition in Experiment 1

	Component				
	1	2	3	4	Uniqueness
Cotton	0,954				0,0477
Wool	0,936				0,0661
Microfiber cloth	0,932				0,0930
Fur	0,864				0,1672
Sponge	0,853				0,2482
Stockings	0,849				0,1803
Velvet	0,797				0,2888
Honey		0,887			0,0889
Hair conditioner		0,866			0,0854
Shampoo		0,858			0,0919
Shower gel		0,847			0,1045
Hand cream		0,839			0,1069
Latex gloves	0,467	0,738			0,1924
Rubber band	0,527	0,532	0,348		0,3176
Stone			0,935		0,0437
Wood balls			0,928		0,0949
Scourer			0,903		0,1473
Sandpaper			0,878		0,0819
Tennis balls	0,458	-0,365	0,730		0,1191
Glass balls			0,640		0,5391
Kinetic sand				0,971	0,0370
Flour				0,911	0,1146
Sand		-0,314		0,893	0,0284
Black pepper		-0,361		0,880	0,0423
Sugar	-0,356	-0,314	0,337	0,772	0,0655

Note. 'varimax' rotation was used

Table E.5. Component Loadings of Materials in Photo Condition in Experiment 1

	Component				
	1	2	3	4	Uniqueness
Cotton	0,946				0,0751
Stockings	0,884				0,1321
Microfiber cloth	0,868	-0,358			0,1111
Sponge	0,861				0,2239
Wool	0,807	-0,459			0,1251
Velvet	0,780			-0,338	0,2596
Latex gloves	0,753	0,461			0,1401
Fur	0,747				0,3373
Shampoo		0,935			0,0269
Shower gel		0,932			0,0503
Hair conditioner		0,926			0,0431
Hand cream		0,922			0,0376
Honey		0,900			0,0823
Wood balls			0,963		0,0658
Tennis balls			0,929		0,1202
Glass balls			0,894		0,1588
Stone		-0,346	0,768	0,457	0,0546
Scourer	0,388		0,645		0,3685
Rubber band	0,517		0,562		0,2874
Sandpaper	0,463	-0,348	0,559	0,365	0,2193
Kinetic sand				0,950	0,0669
Flour				0,911	0,0840
Sand		-0,352		0,895	0,0407
Sugar		-0,363		0,813	0,0835
Black pepper	0,946	-0,458	0,498	0,655	0,0768

Note. 'varimax' rotation was used

Table E. 6. Component Loadings of Materials in Video Condition in Experiment 1

	Component				
	1	2	3	4	Uniqueness
Stockings	0.958				0,0679
Cotton	0,930				0,0359
Sponge	0,906				0,1304
Microfiber cloth	0,882	-0,336			0,0991
Wool	0,875	-0,330			0,0986
Latex gloves	0,795	0,477			0,0659
Velvet	0,698			-0,314	0,4009
Rubber band	0,684	0,417		0,316	0,2101
Fur	0,658			-0,385	0,3780
Scourer	0,573		0,535		0,3791
Honey		0,956			0,0392
Shower gel		0,945			0,0409
Hair conditioner		0,942			0,0495
Hand cream		0,940			0,0354
Shampoo		0,933			0,0387
Tennis balls			0,935		0,1120
Wood balls			0,920		0,1056
Glass balls			0,906		0,1130
Stone		-0,333	0,868		0,0788
Sandpaper			0,864		0,1511
Black pepper		-0,528	0,682	0,344	0,0734
Kinetic sand				0,820	0,2073
Flour		-0,307		0,790	0,2792
Sand		-0,514		0,769	0,1095
Sugar	0.958	-0,510	0,304	0,642	0,1501

Note. 'varimax' rotation was used

F. ANOVA TABLE OF EXPERIMENT 1

Table F. 1. ANOVA Table for Experiment 1

Effect	*DFn*	*DFd*	*F*	*p*	*p<.05*	*ges*
Condition	2	86	0.486	0.617		0.000768
Adjective	22	1892	65.795	1.47e-4	*	0.097
Material	24	2064	137.943	0	*	0.101
Condition:Adjective	44	1892	1.975	0.000161	*	0.006
Condition:Material	48	2064	4.609	1.43e-22	*	0.007
Adjective:Material	528	45408	96.85	0	*	0.448
Condition:Adjective:Material	1056	45408	3.522	1.77e-76	*	0.056

G. ANOVA GRAPHS OF EXPERIMENT 1

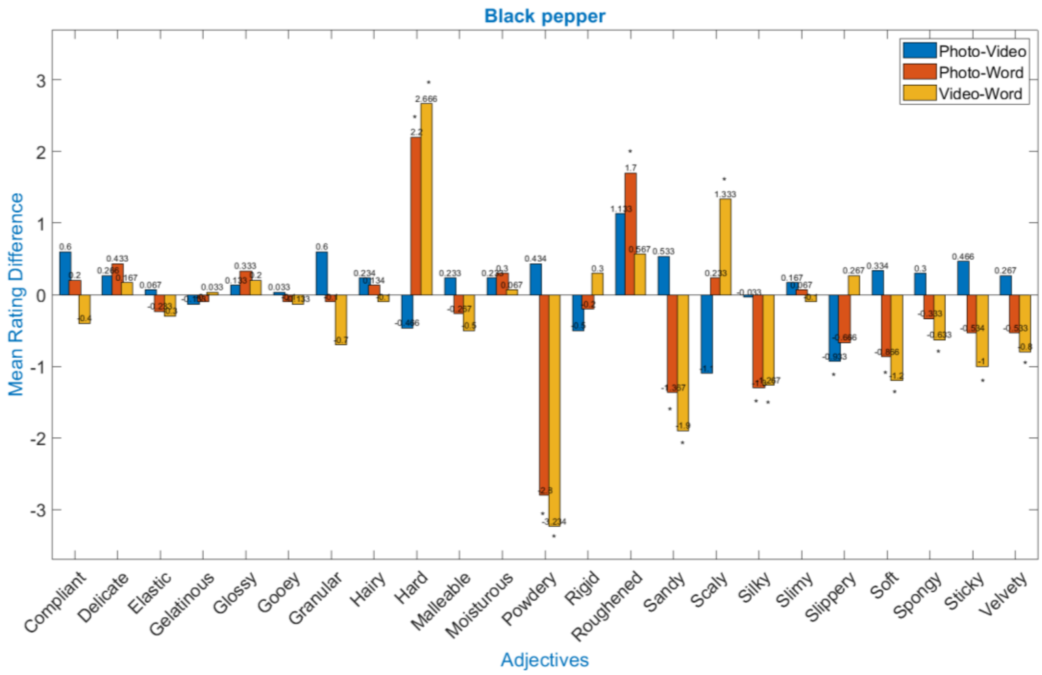


Figure G.1. Bar graphs of mean rating differences of black pepper. Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

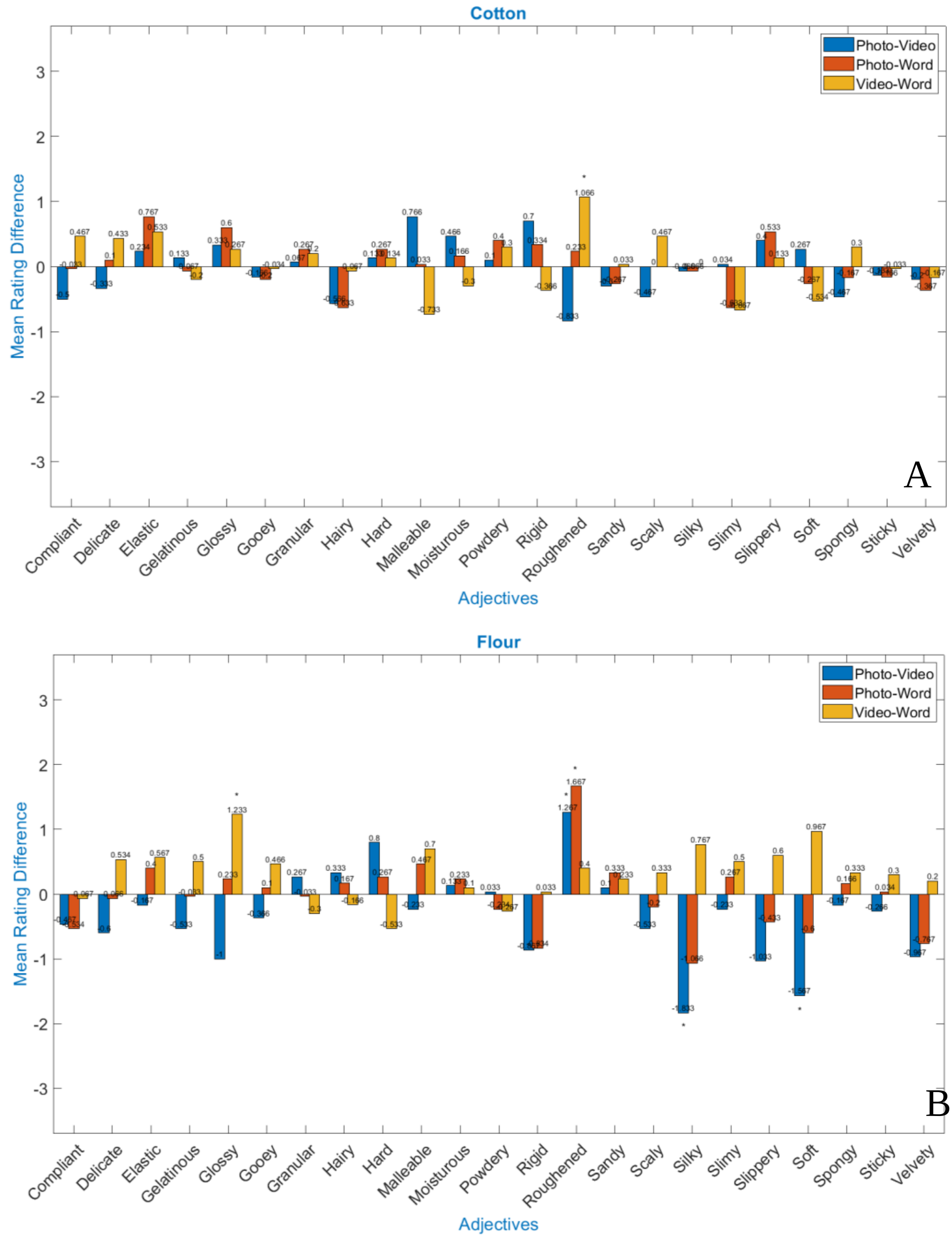


Figure G.2. Bar graphs of mean rating differences of cotton (A) and flour (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

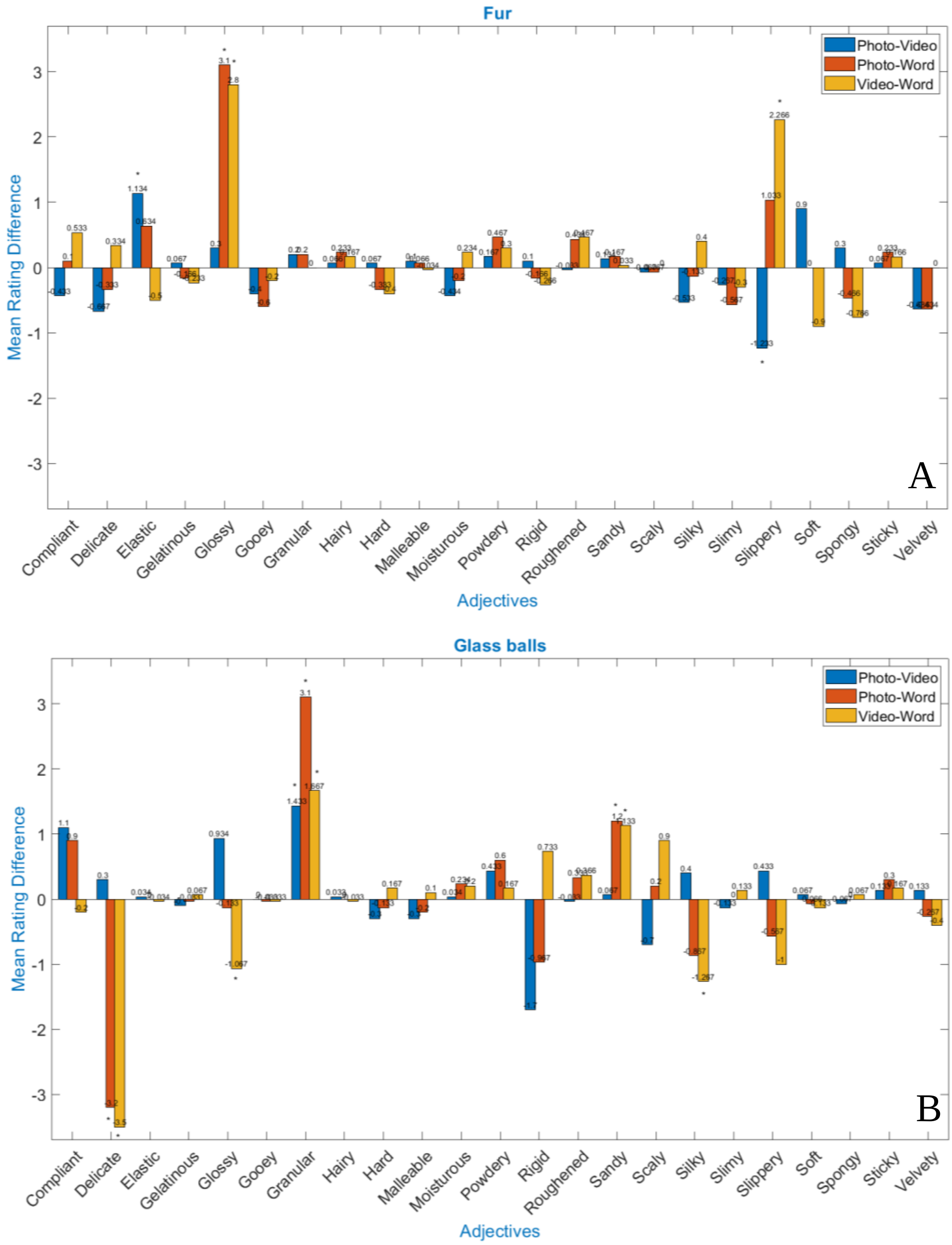


Figure G.3. Bar graphs of mean rating differences fur (A) and glass balls (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

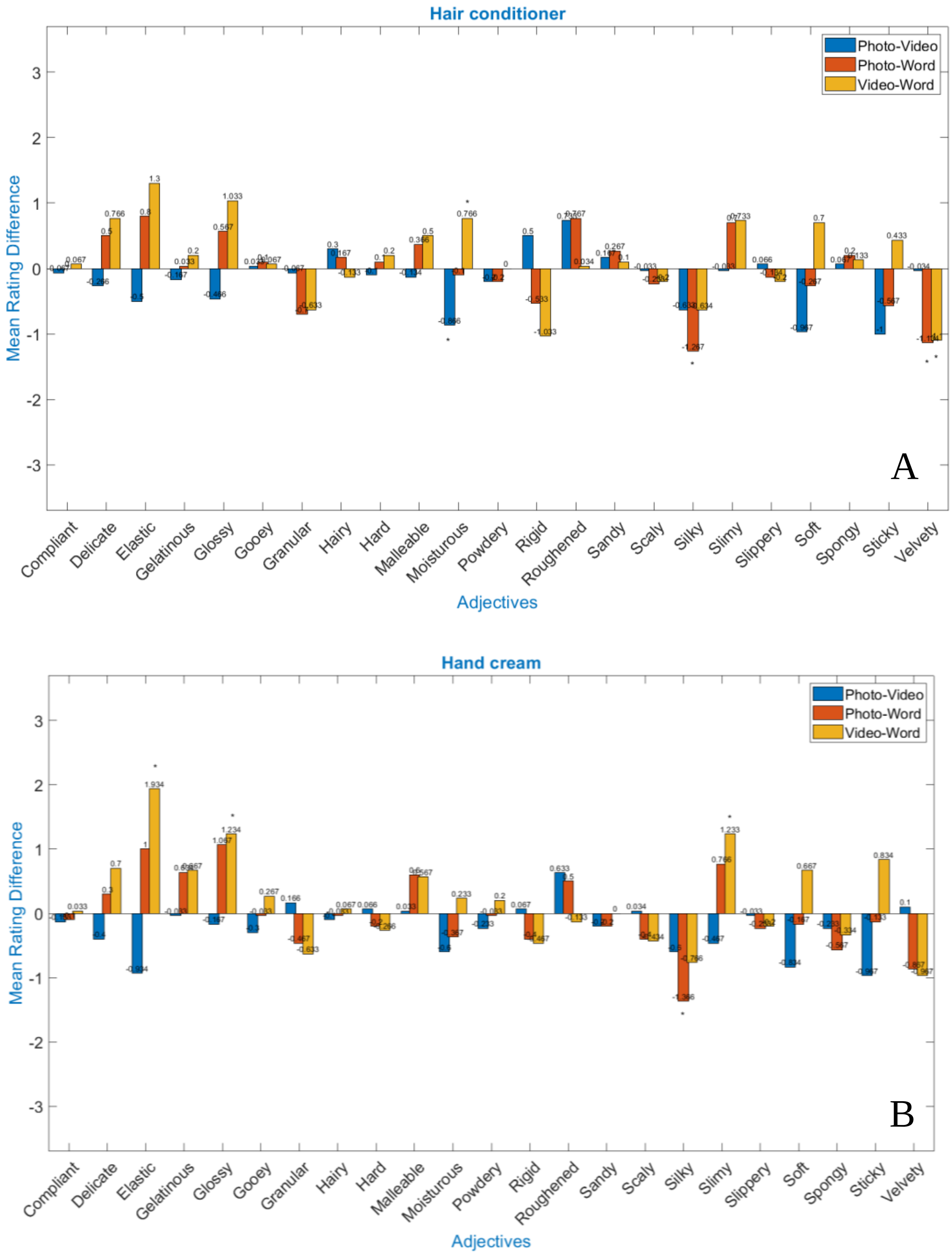


Figure G.4. Bar graphs of mean rating differences of hair conditioner (A) and hand cream (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

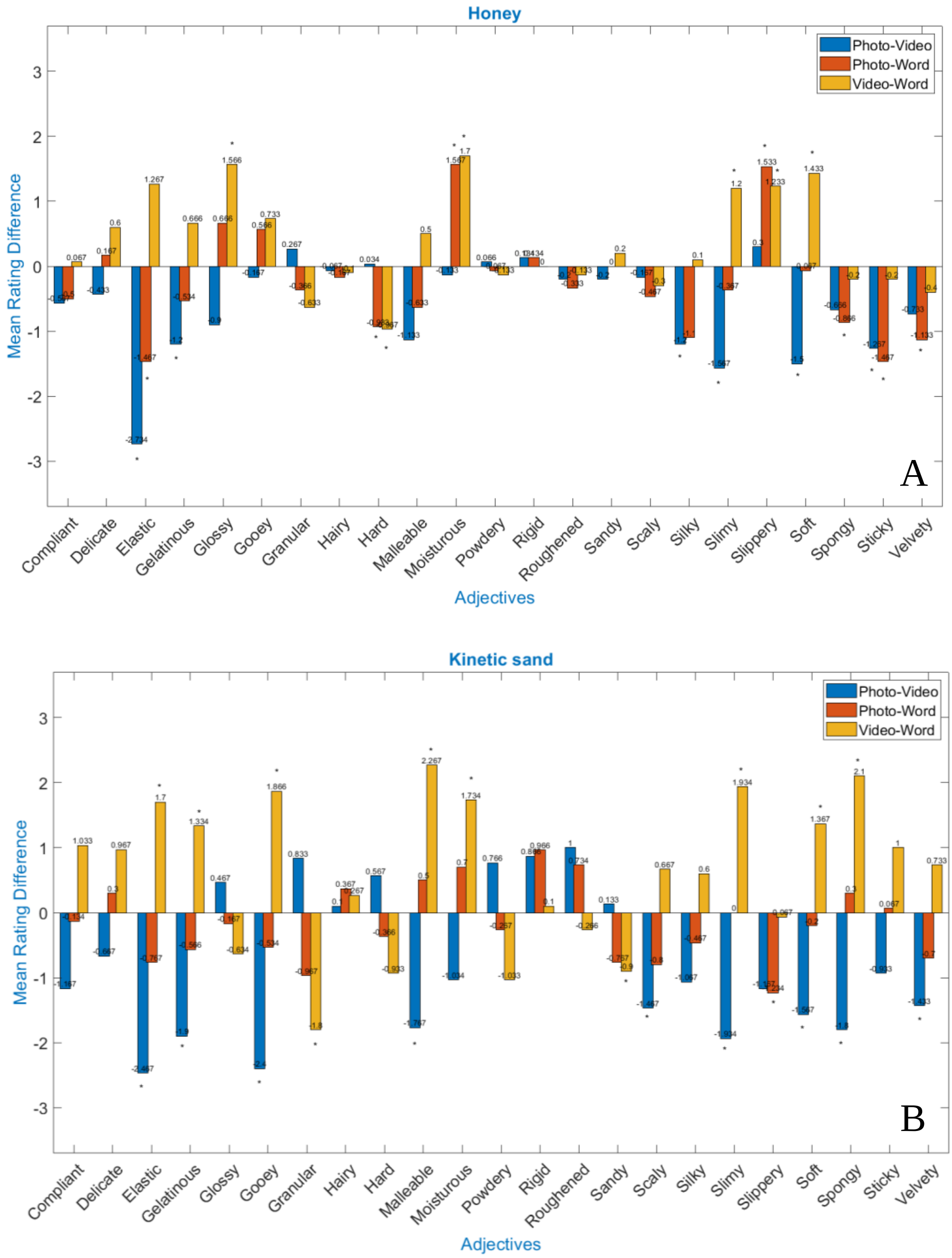
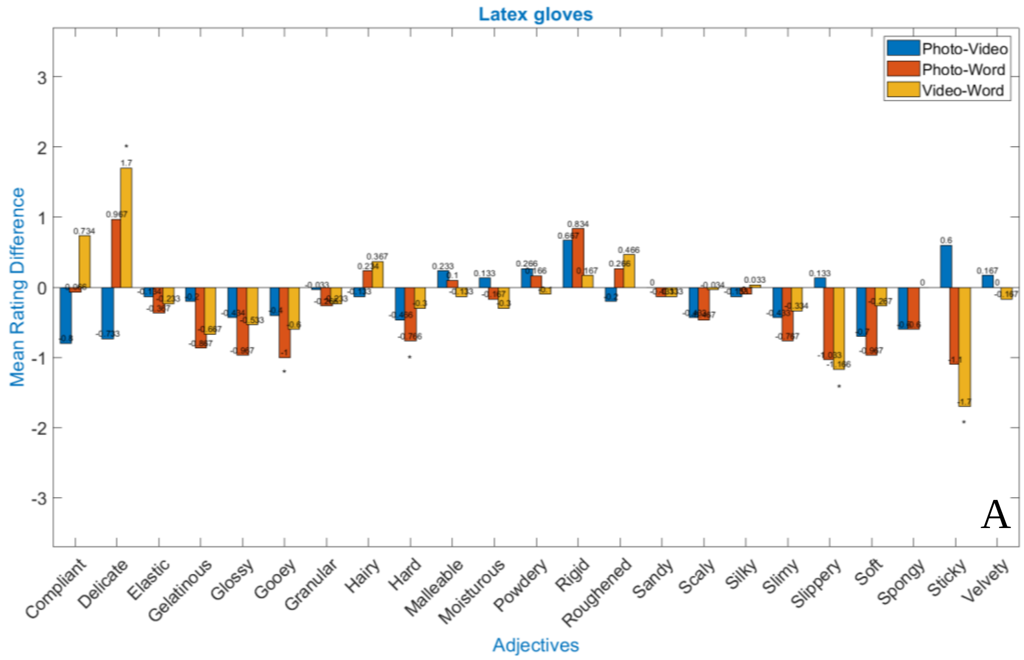


Figure G.5. Bar graphs of mean rating differences of honey (A) and kinetic sand (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.



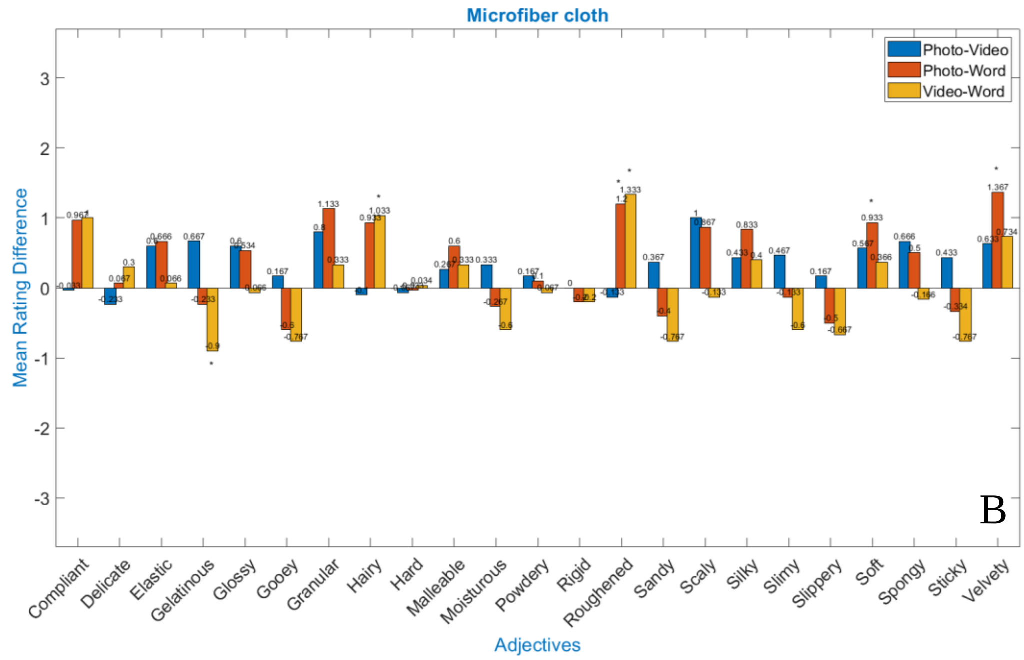
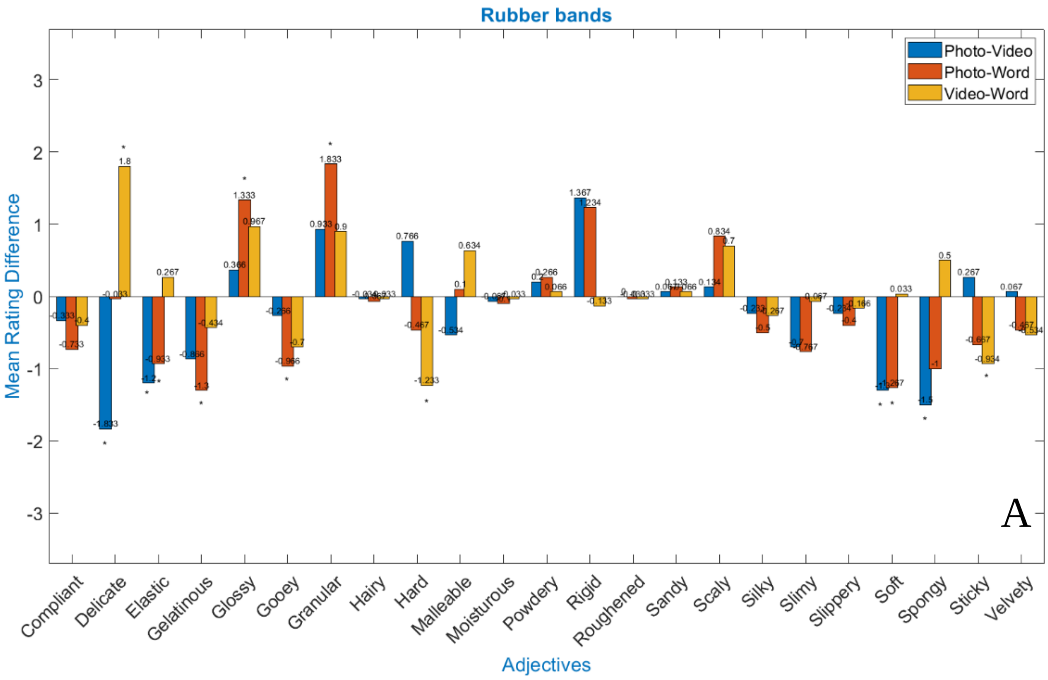


Figure G.6. Bar graphs of mean rating differences of latex gloves (A) and microfiber cloth (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.



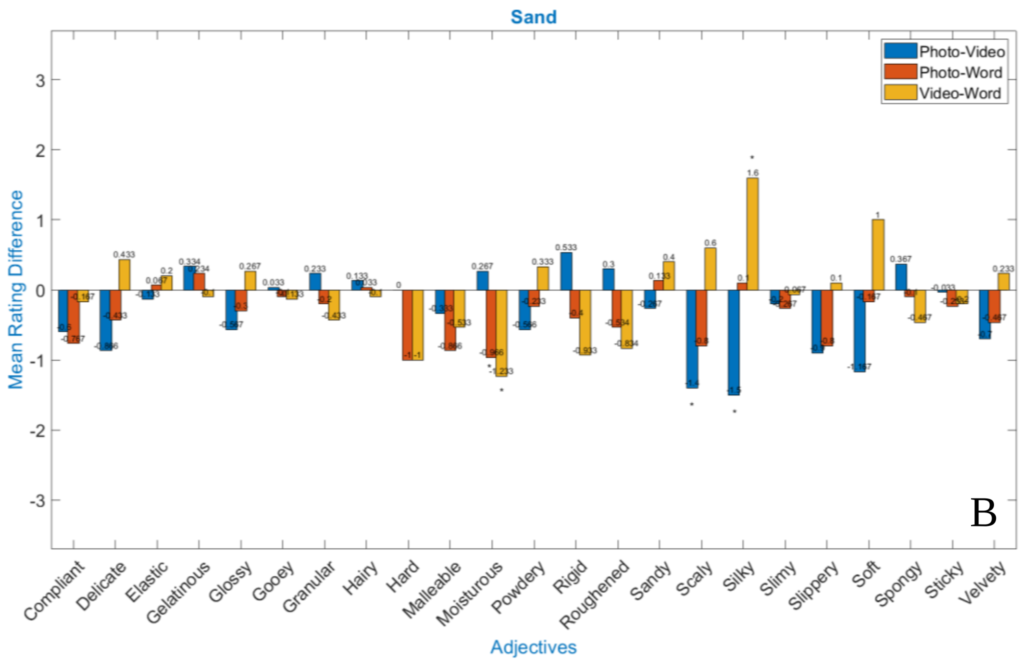


Figure G.7. Bar graphs of mean rating differences of rubber bands (A) and sand (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

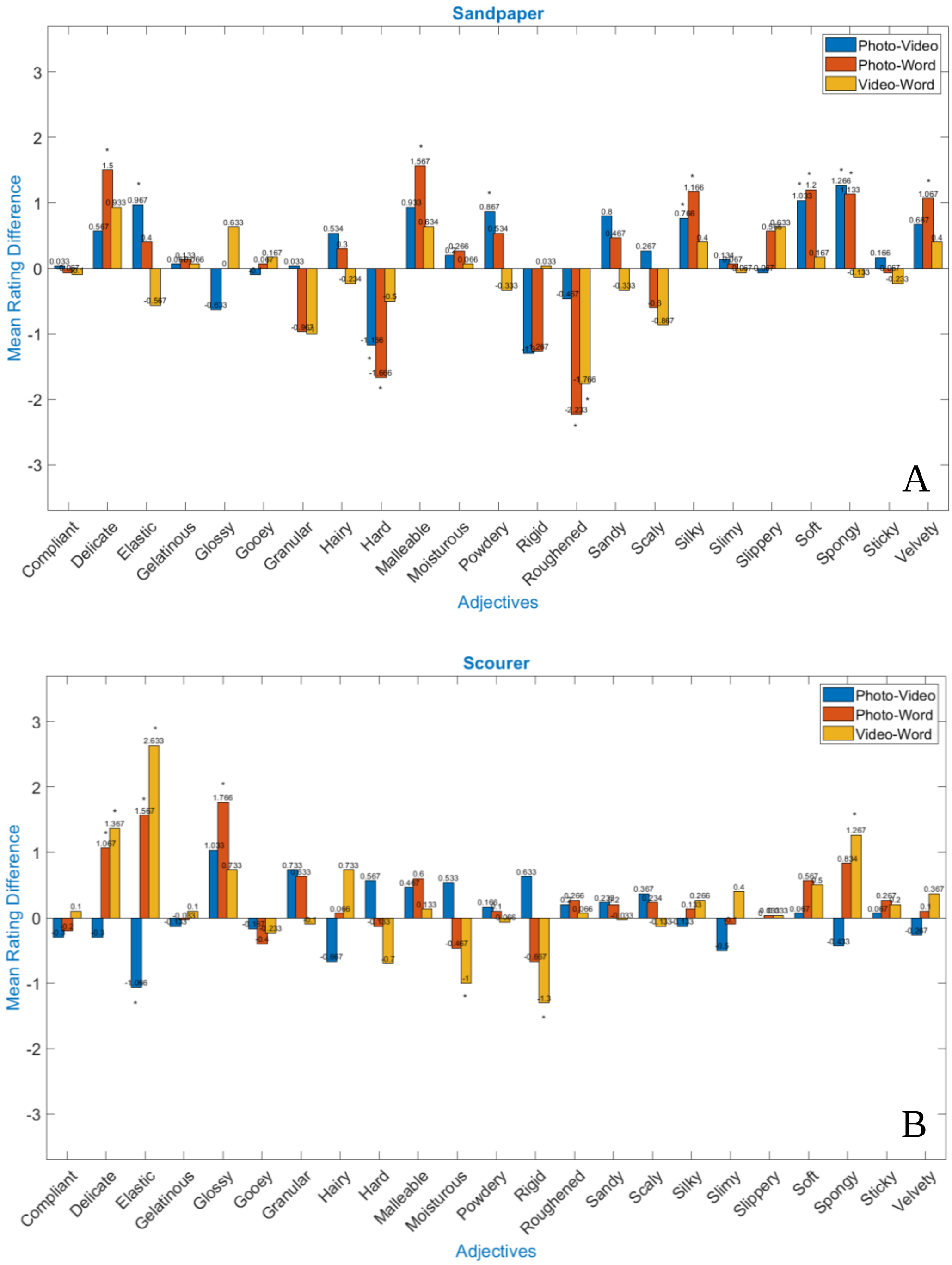


Figure G.8. Bar graphs of mean rating differences of sandpaper (A) and scourer (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

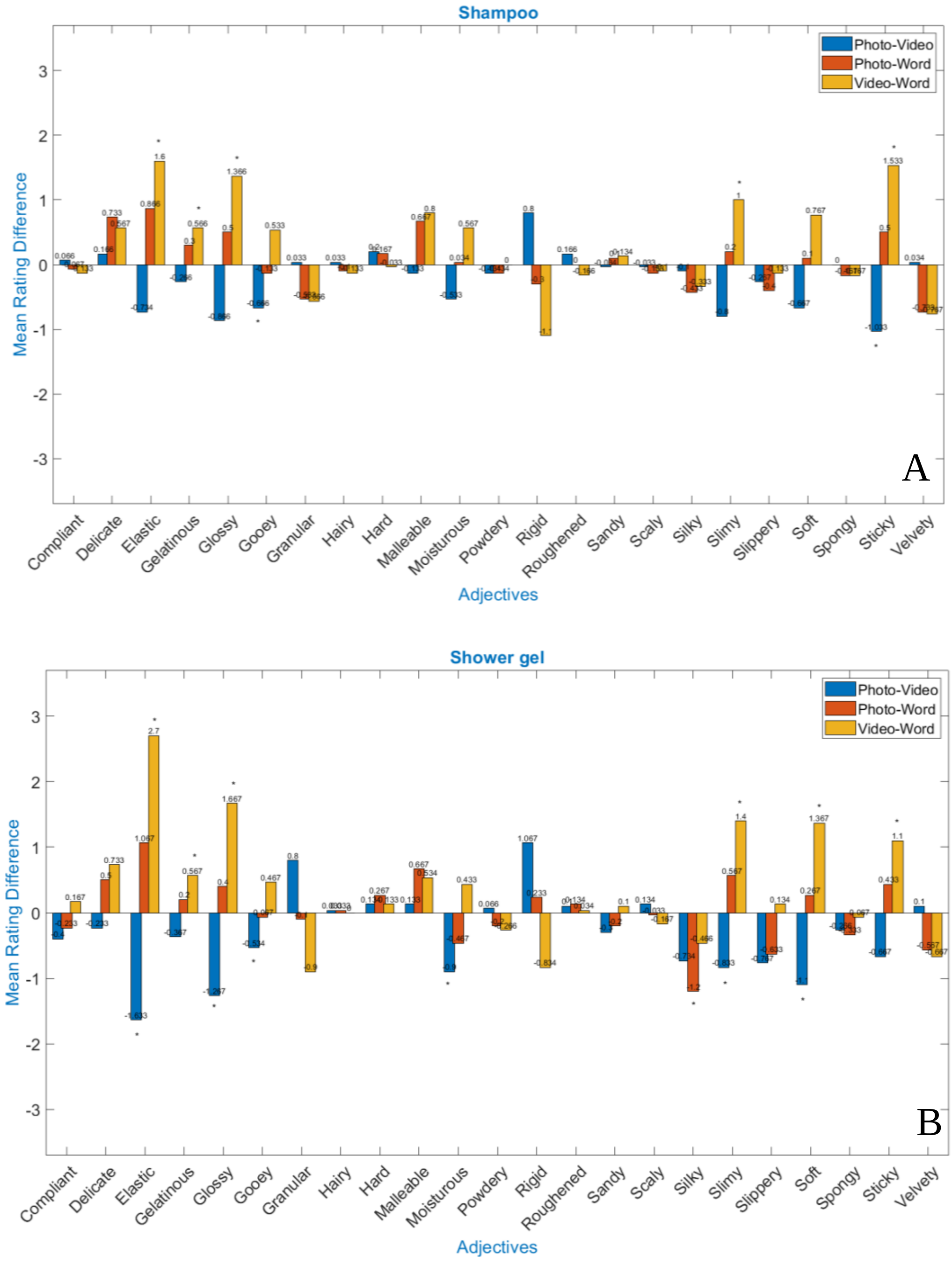


Figure G.9. Bar graphs of mean rating differences of shampoo (A) and shower gel (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

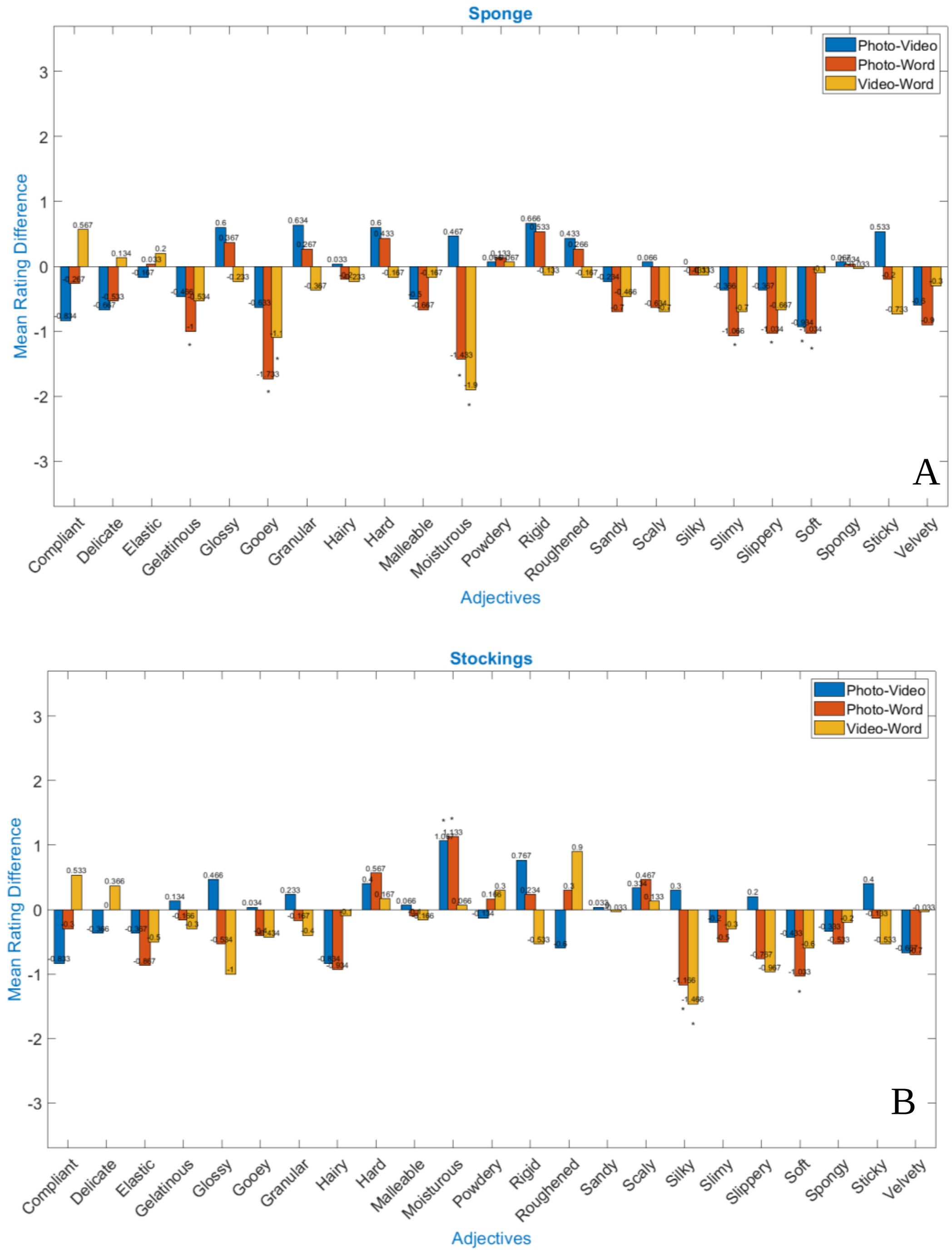


Figure G.10. Bar graphs of mean rating differences of sponge (A) and stockings (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

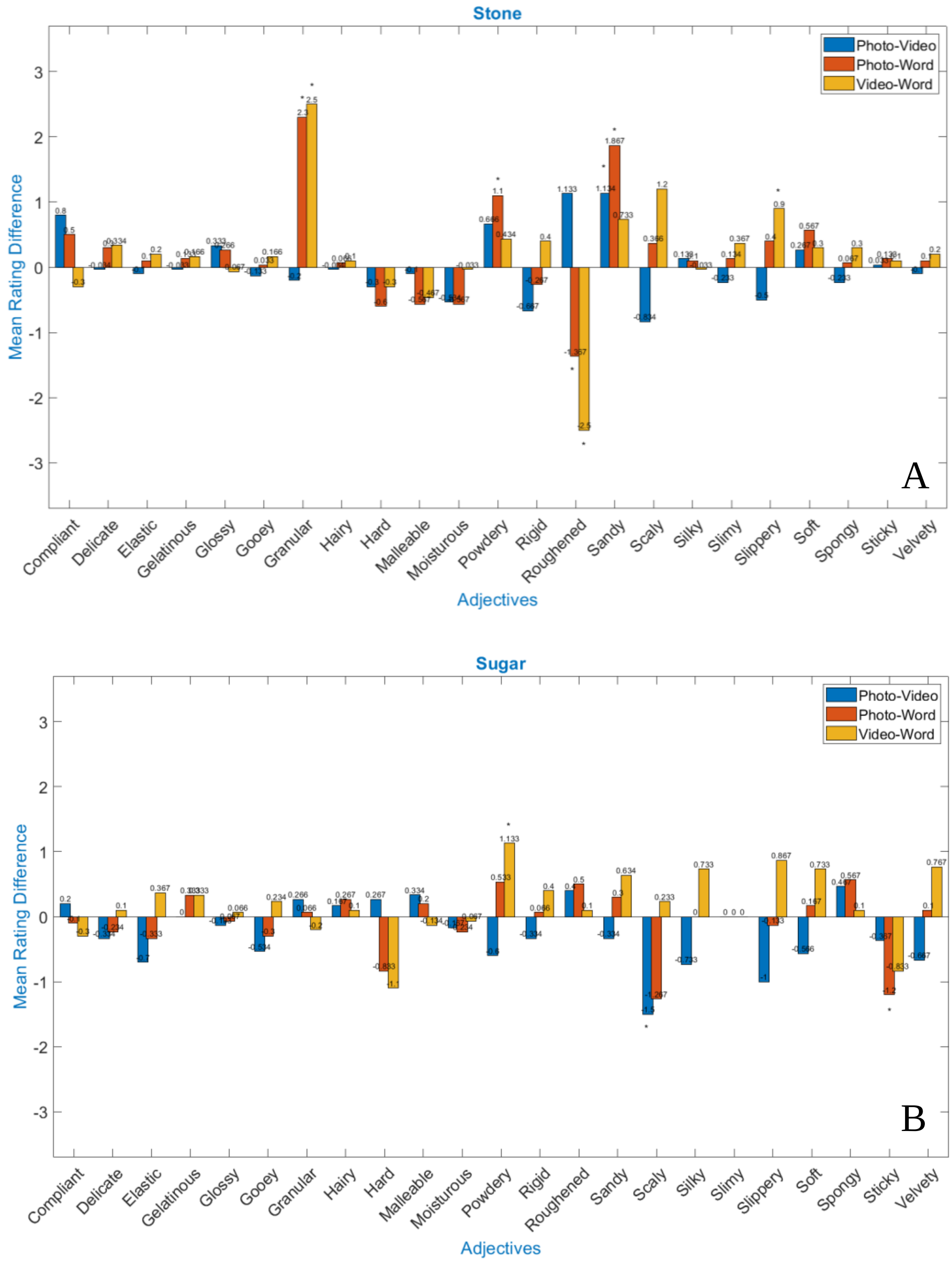


Figure G.11. Bar graphs of mean rating differences of stone (A) and sugar (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

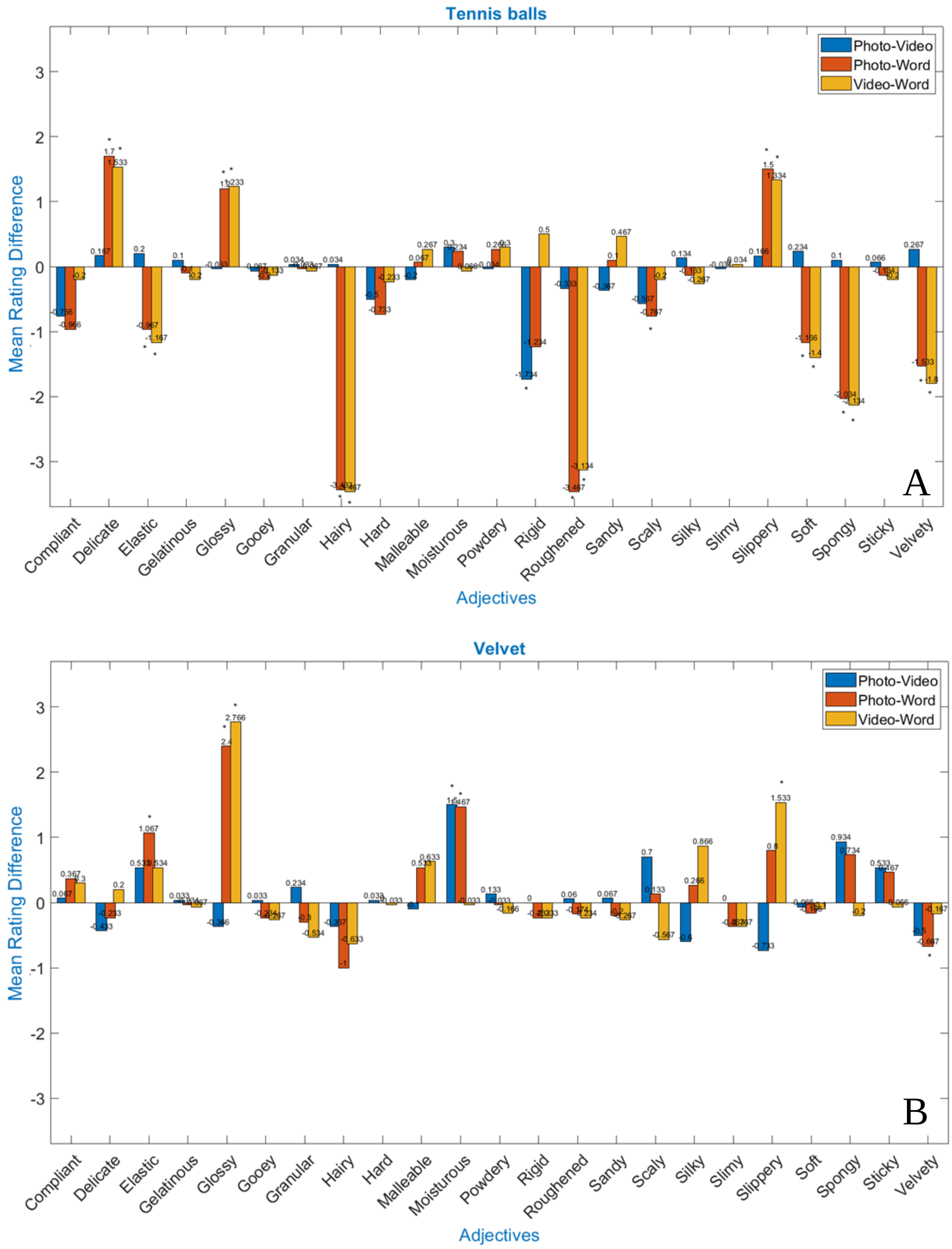


Figure G.12. Bar graphs of mean rating differences of tennis balls (A) and velvet (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

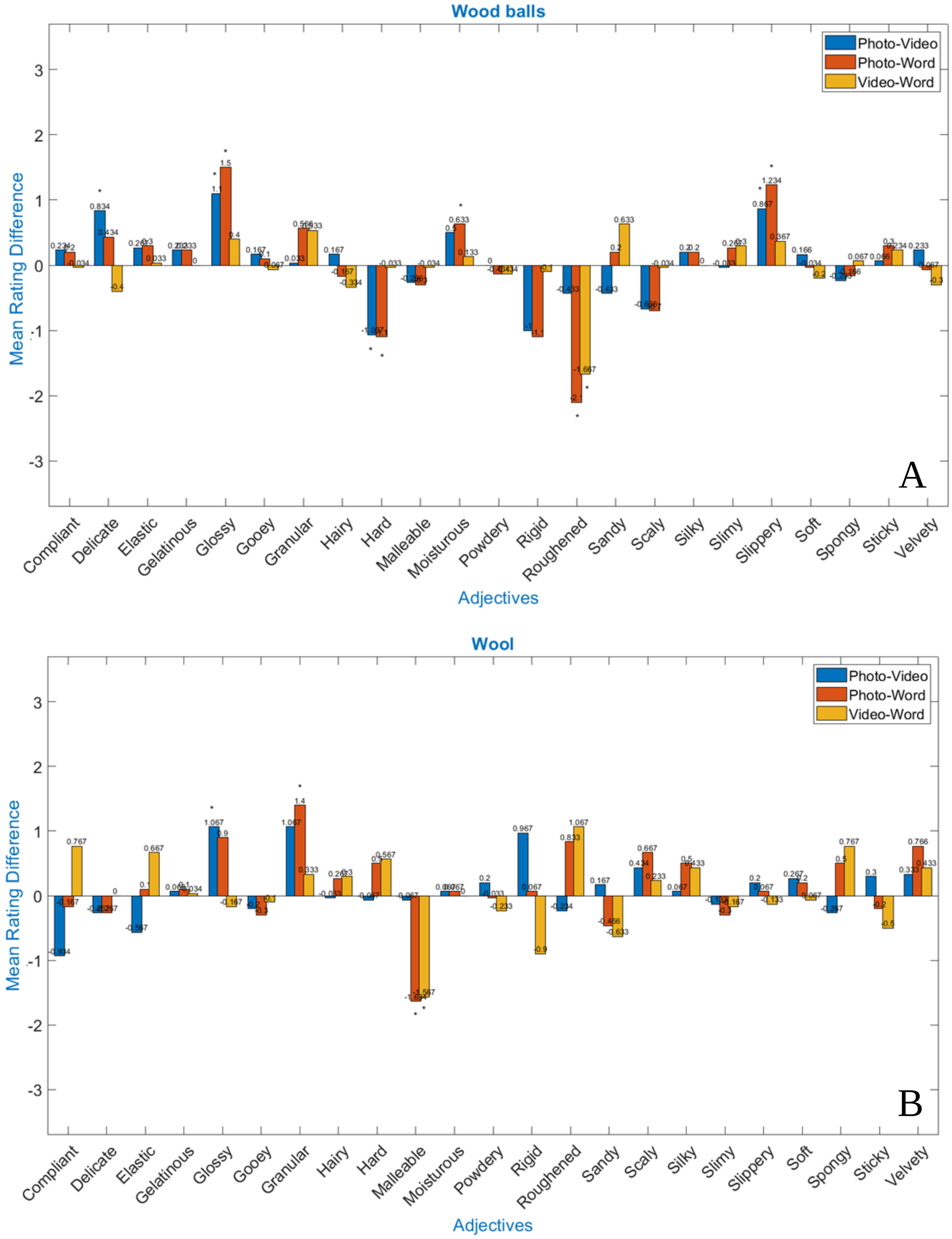


Figure G.13. Bar graphs of mean rating differences of wood balls (A) and wool (B). Y-axis represents the mean differences, and X-axis represents the adjectives. Each bar is a comparison between two conditions depicted by the legend.

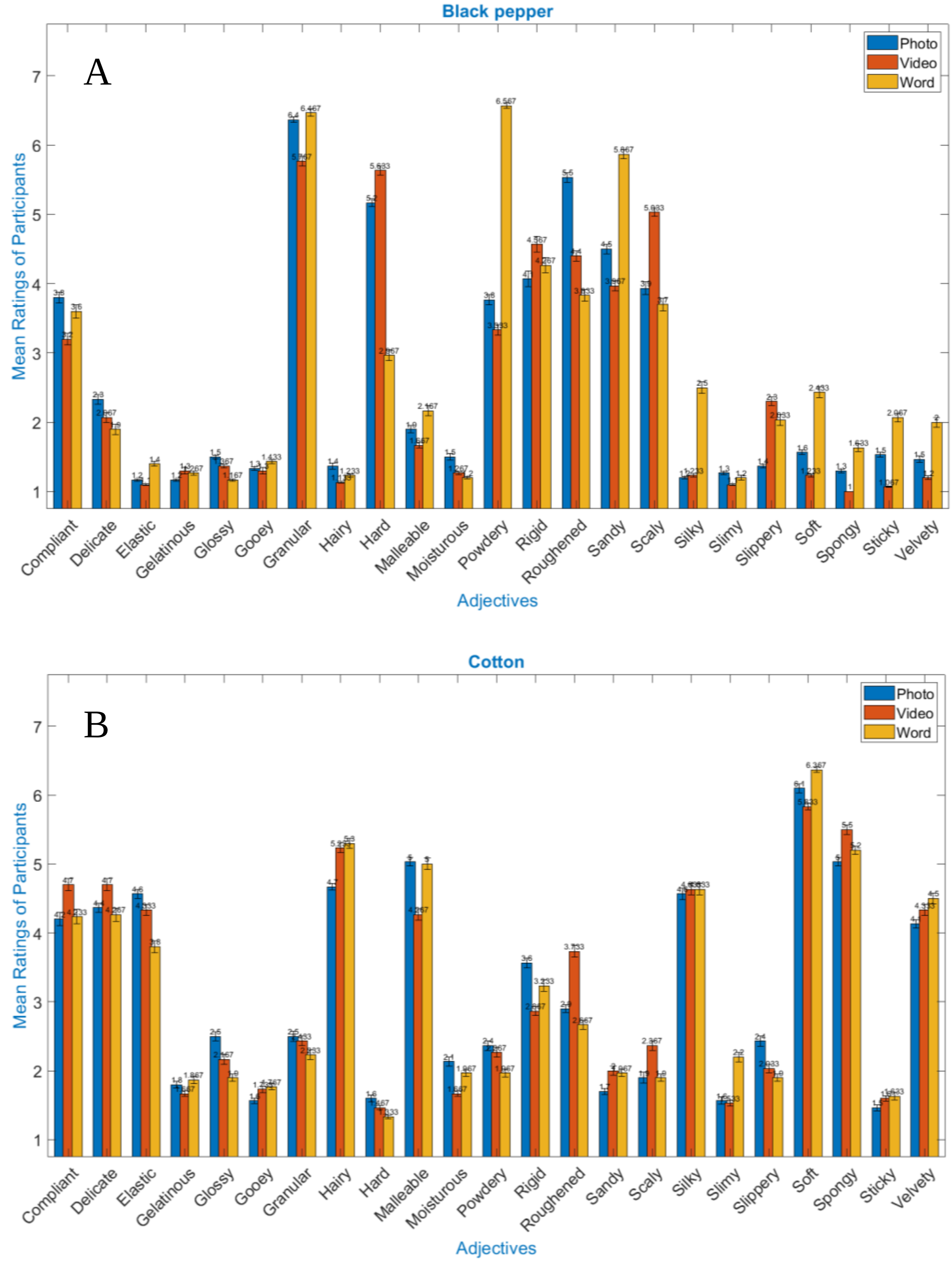
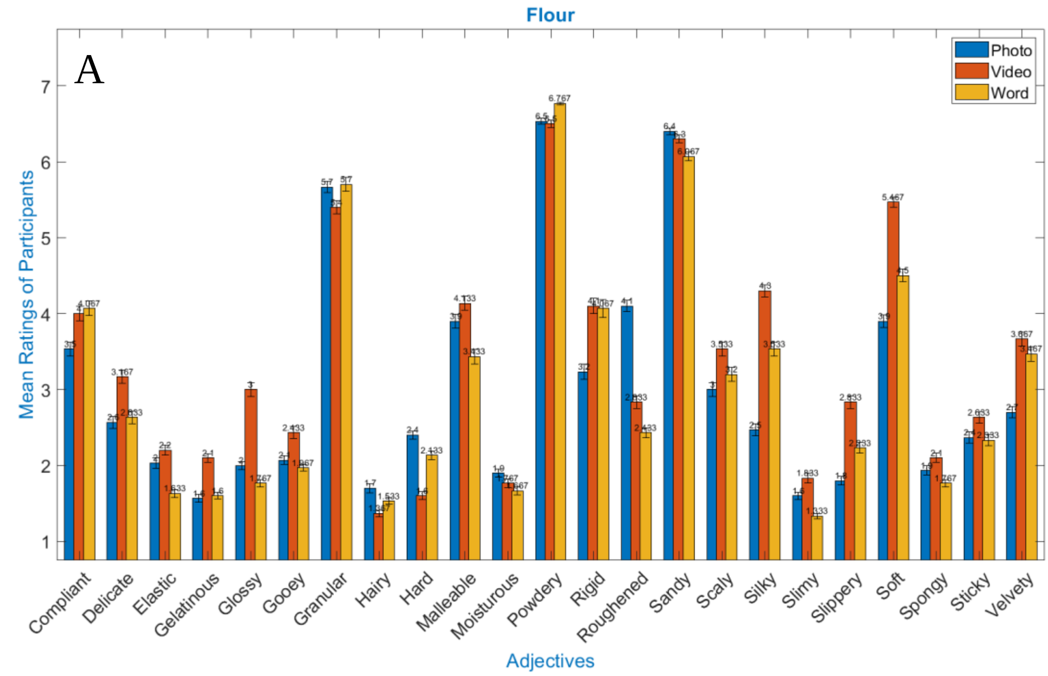


Figure G.14. Bar graphs of mean ratings of black pepper (A) and cotton (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.



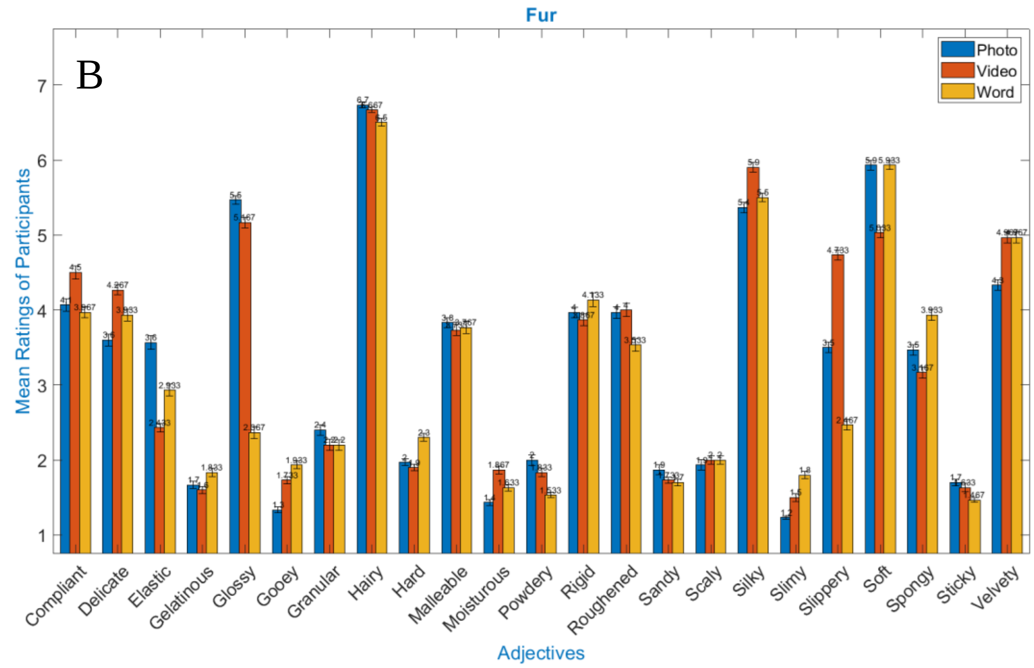


Figure G.15. Bar graphs of mean ratings of flour (A) and fur (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

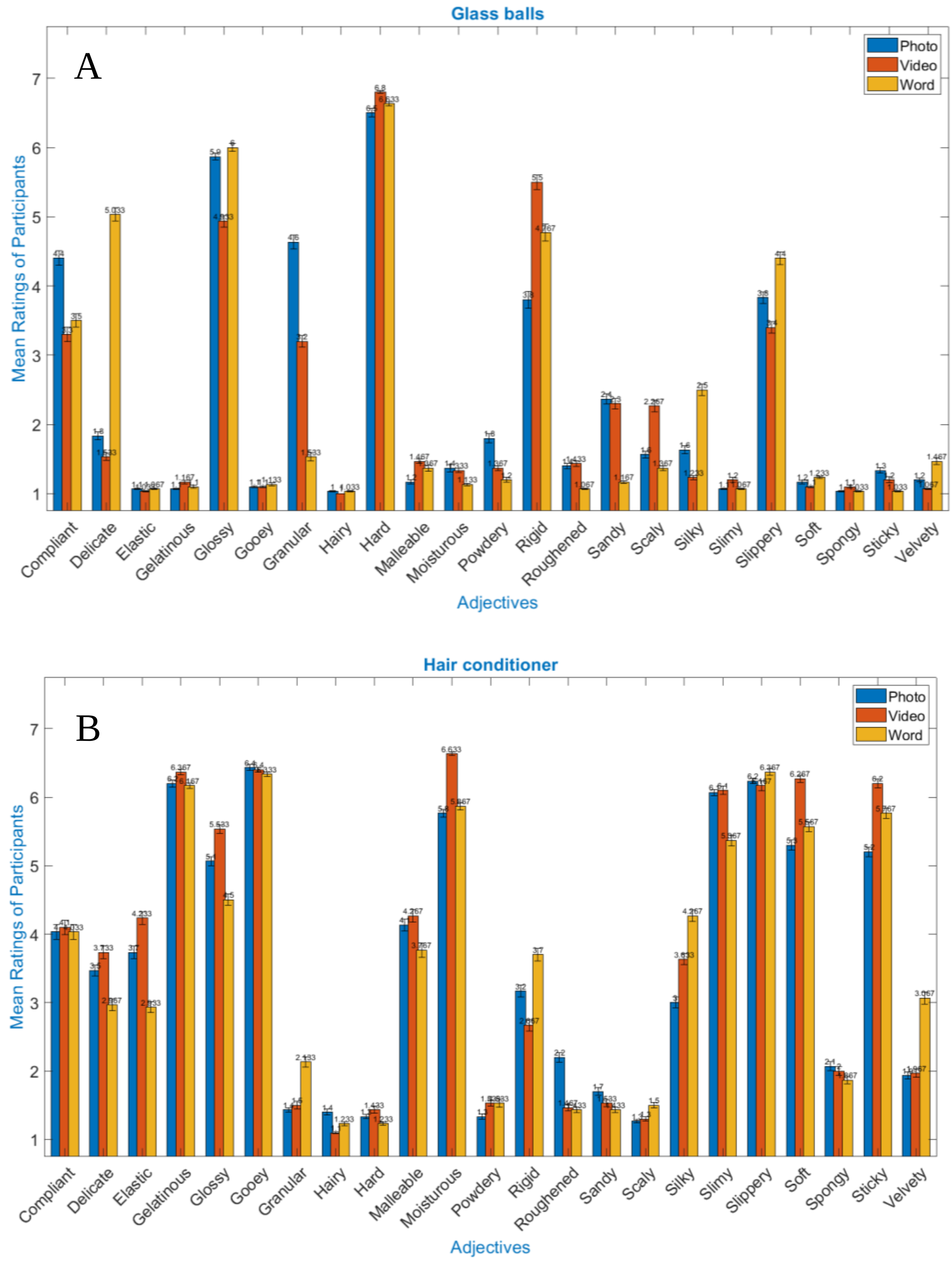


Figure G.16. Bar graphs of mean ratings of glass balls (A) and hair conditioner (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

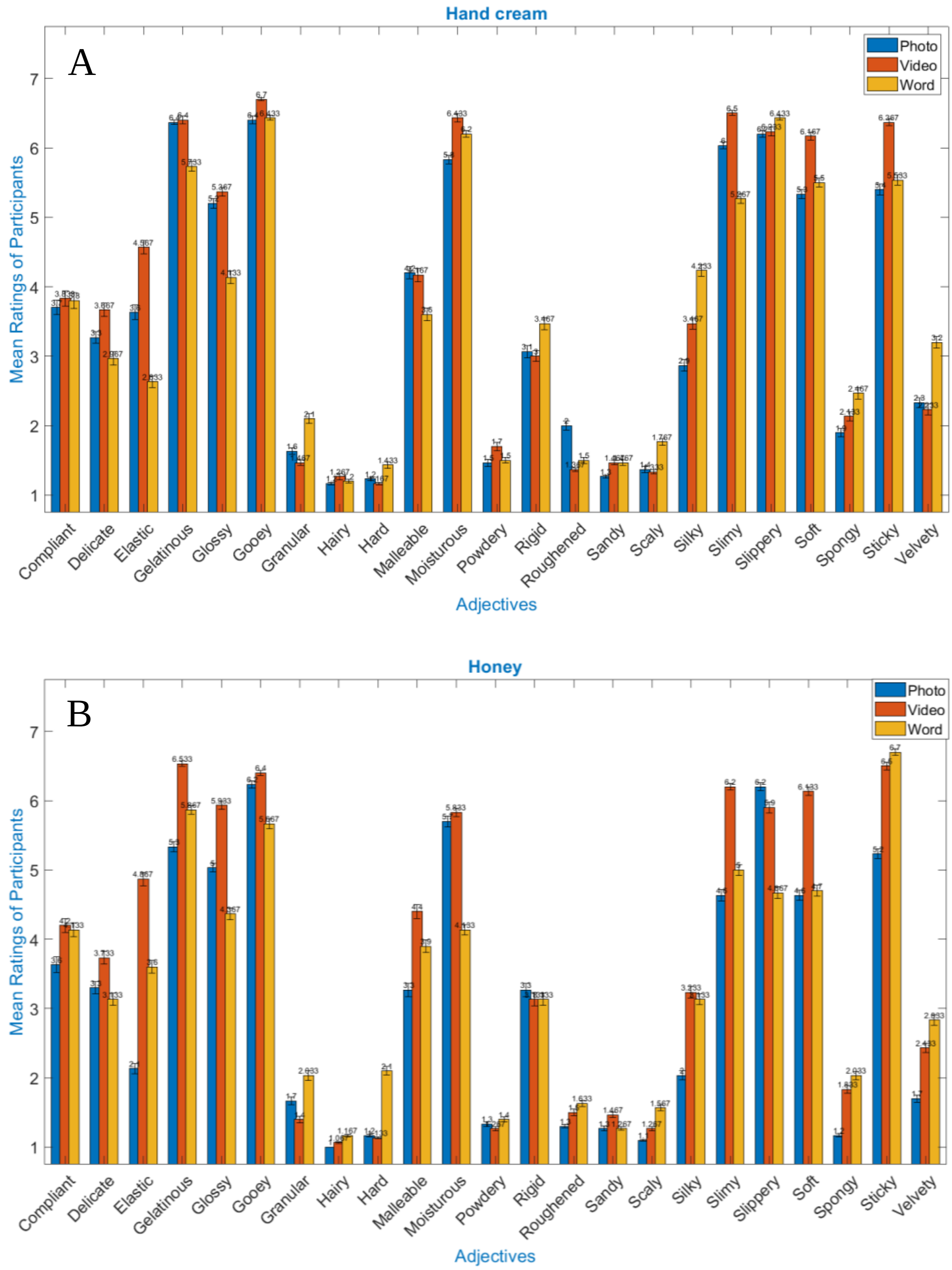


Figure G.17. Bar graphs of mean ratings of hand cream (A) and honey (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

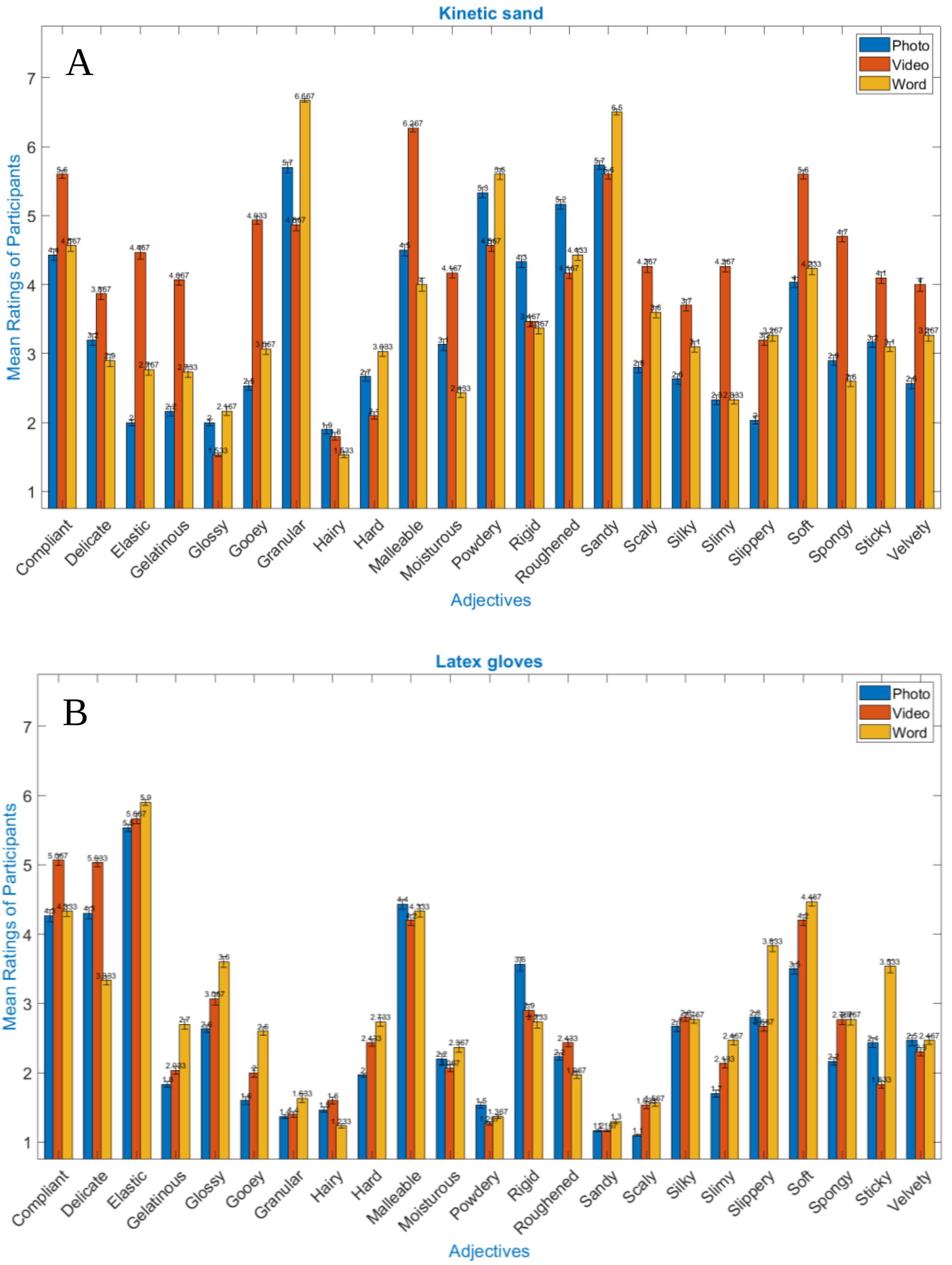
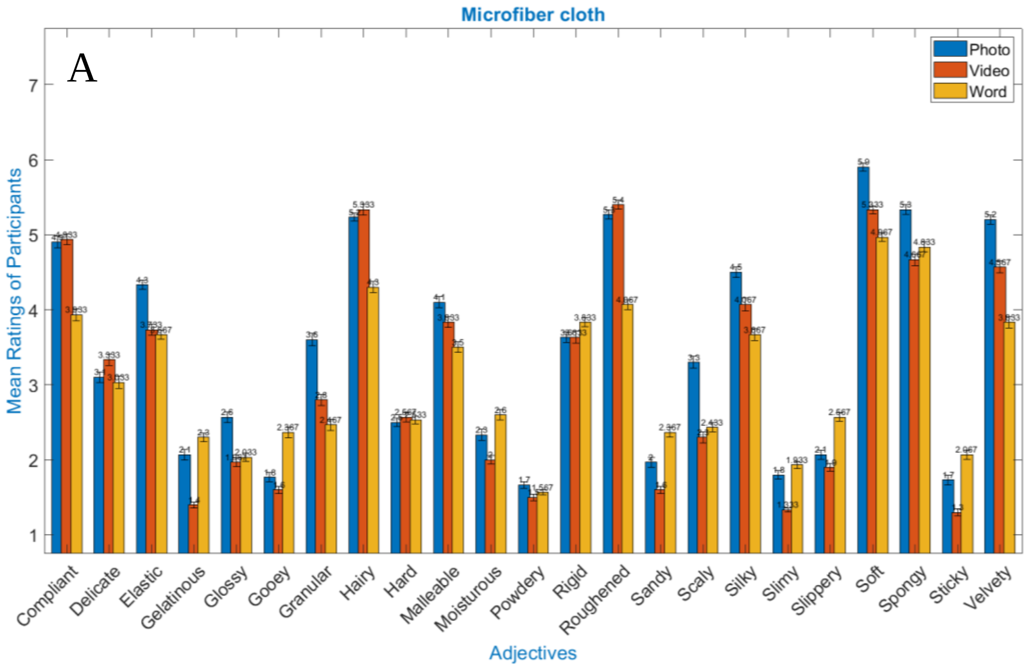


Figure G.18. Bar graphs of mean ratings of kinetic sand (A) and latex gloves (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.



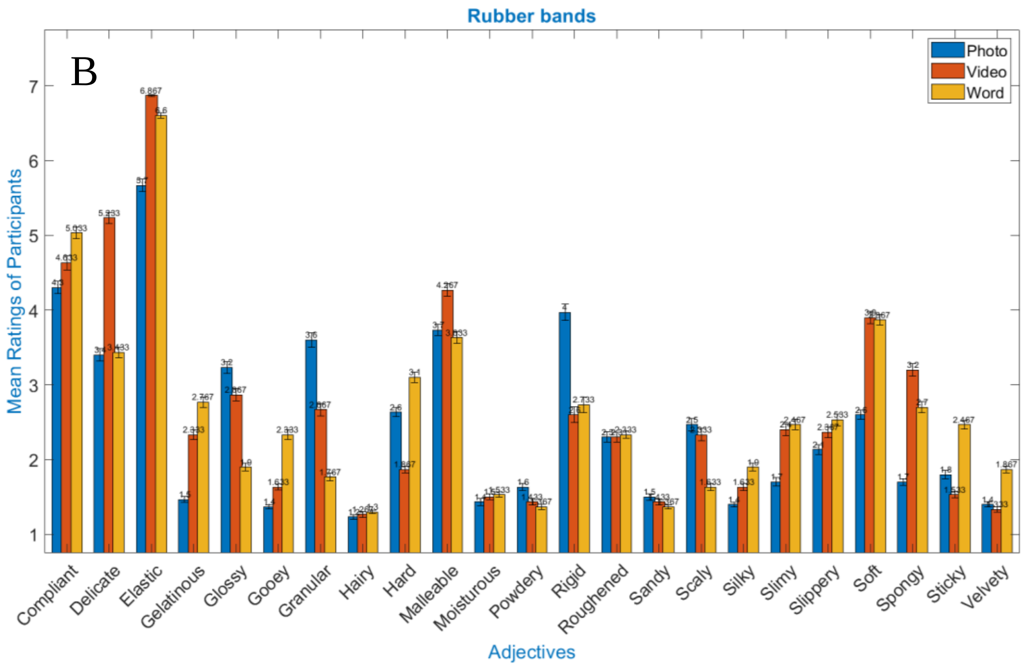


Figure G.19. Bar graphs of mean ratings of microfiber cloth (A), and rubber bands (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

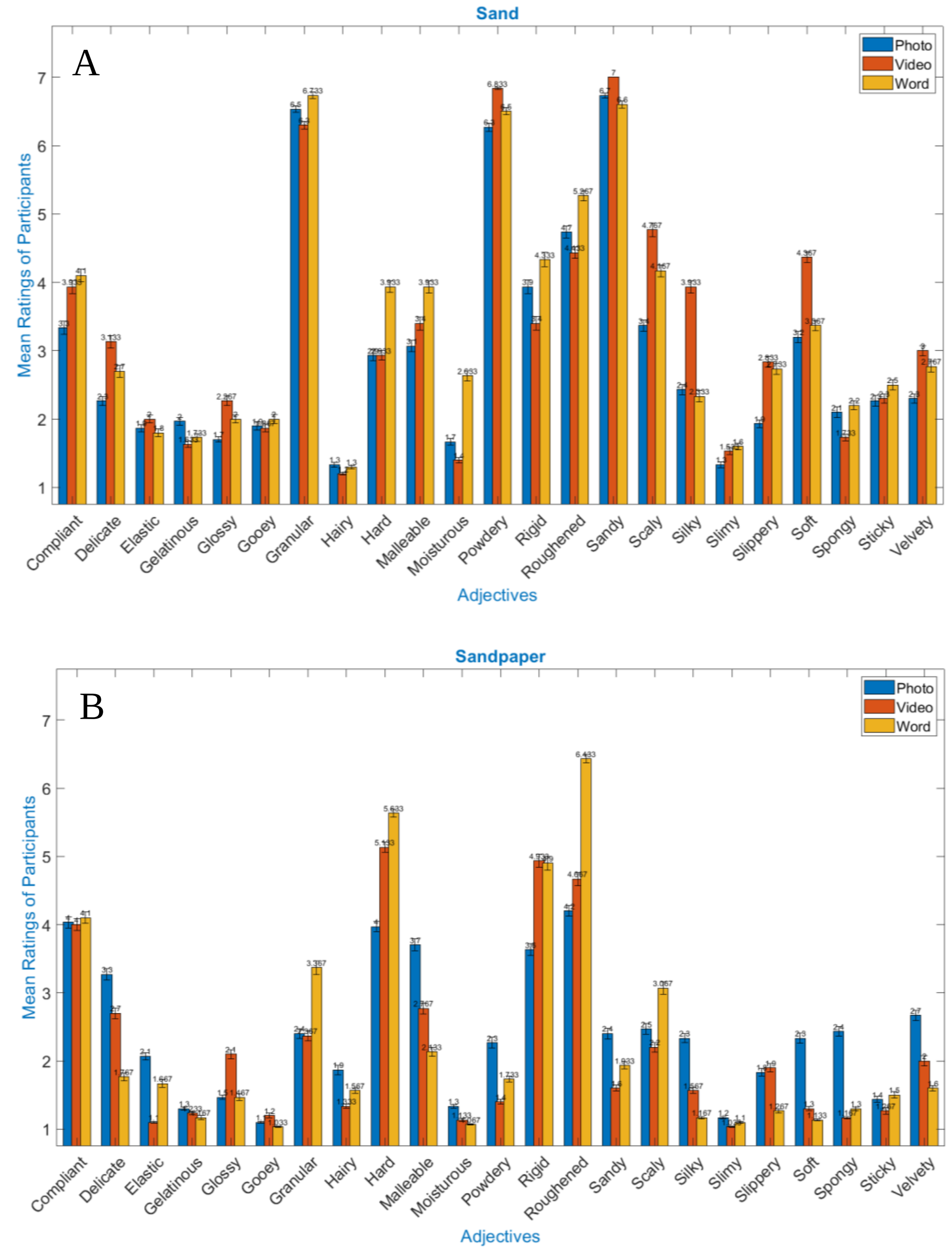


Figure G.20. Bar graphs of mean ratings of sand (A) and sandpaper (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

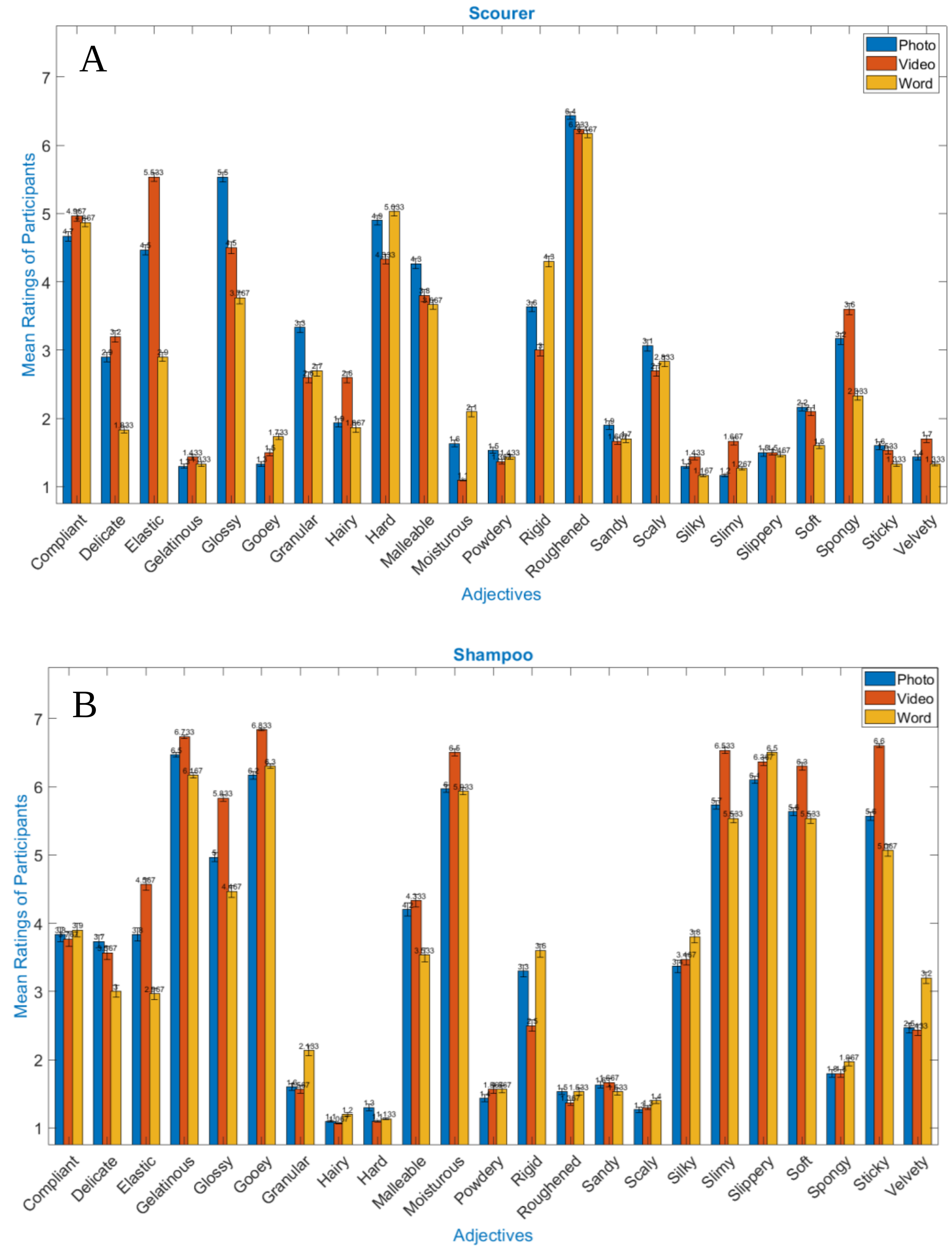


Figure G.21. Bar graphs of mean ratings of scourer (A) and shampoo (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

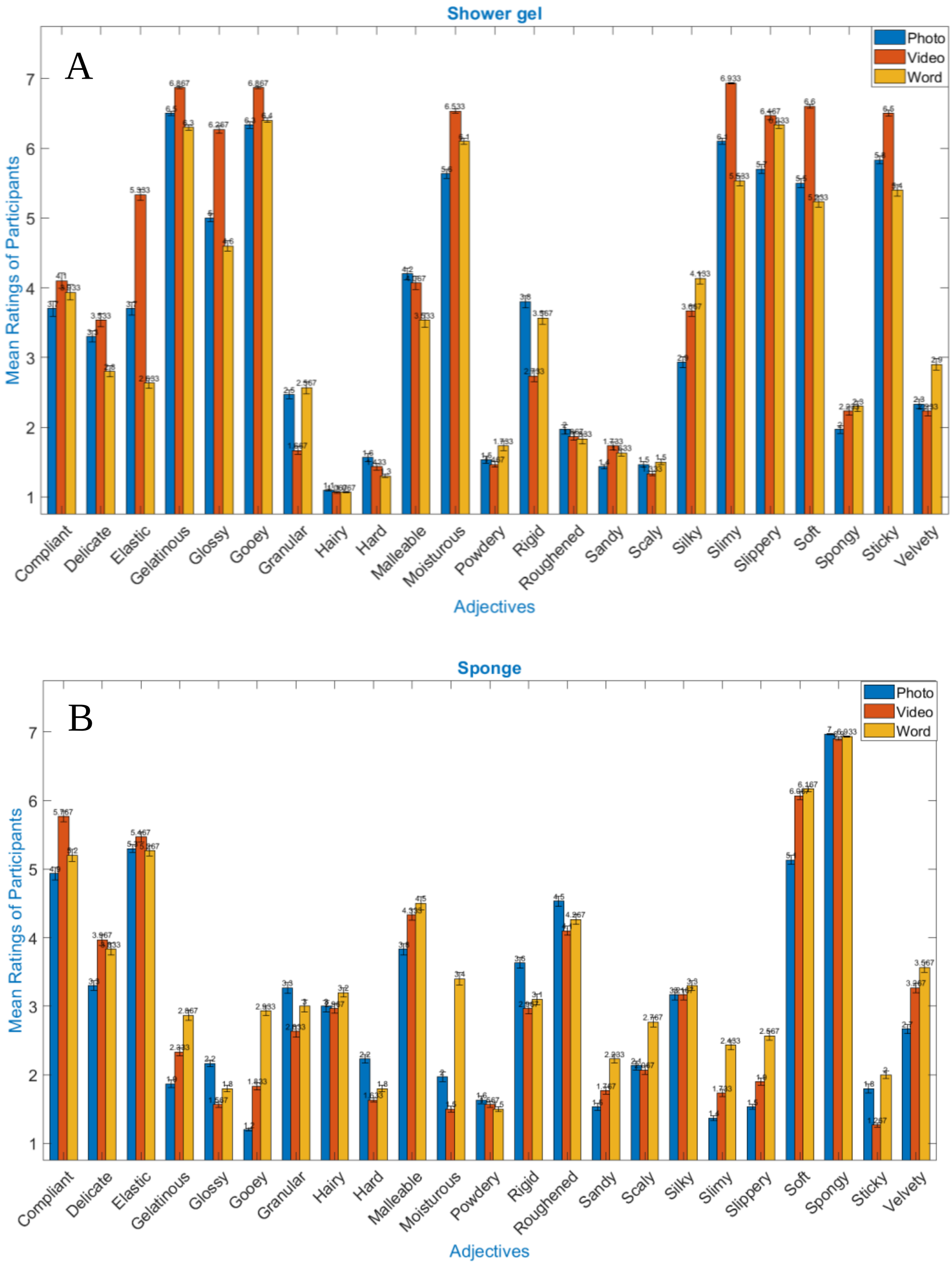


Figure G.22. Bar graphs of mean ratings of shower gel (A) and sponge (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

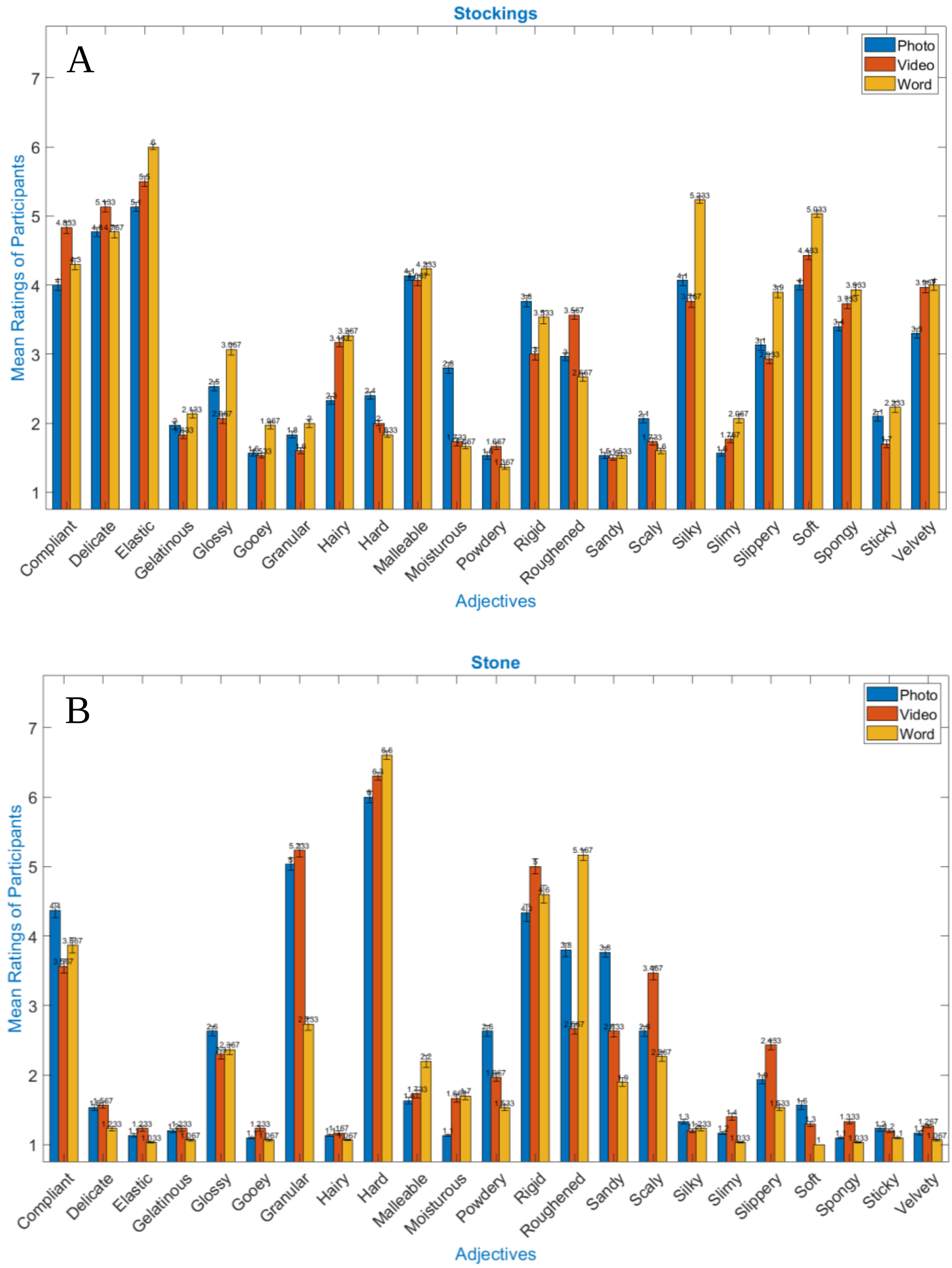


Figure G.23. Bar graphs of mean ratings of stockings (A) and stone (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

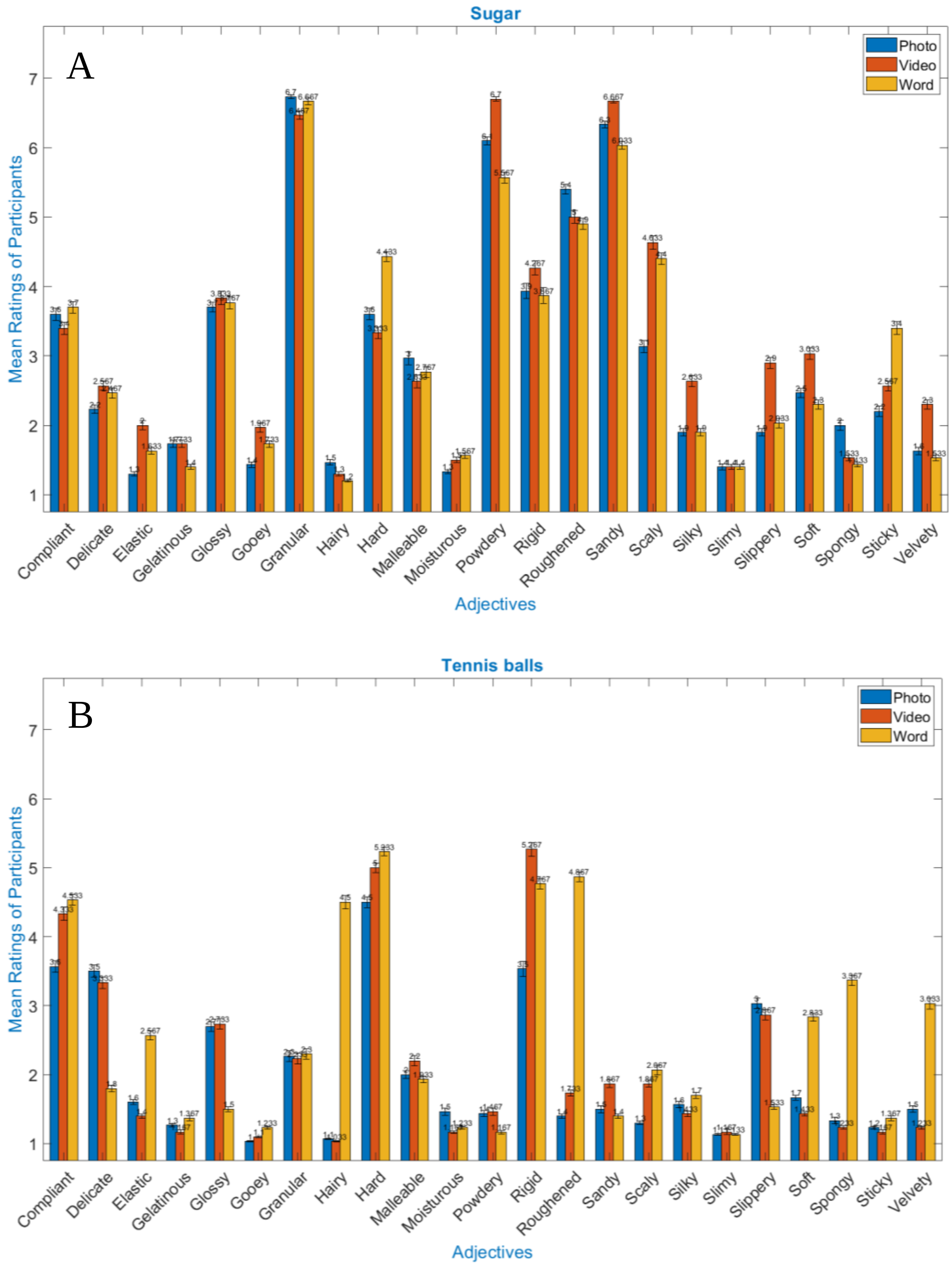


Figure G.24. Bar graphs of mean ratings of sugar (A) and tennis balls (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

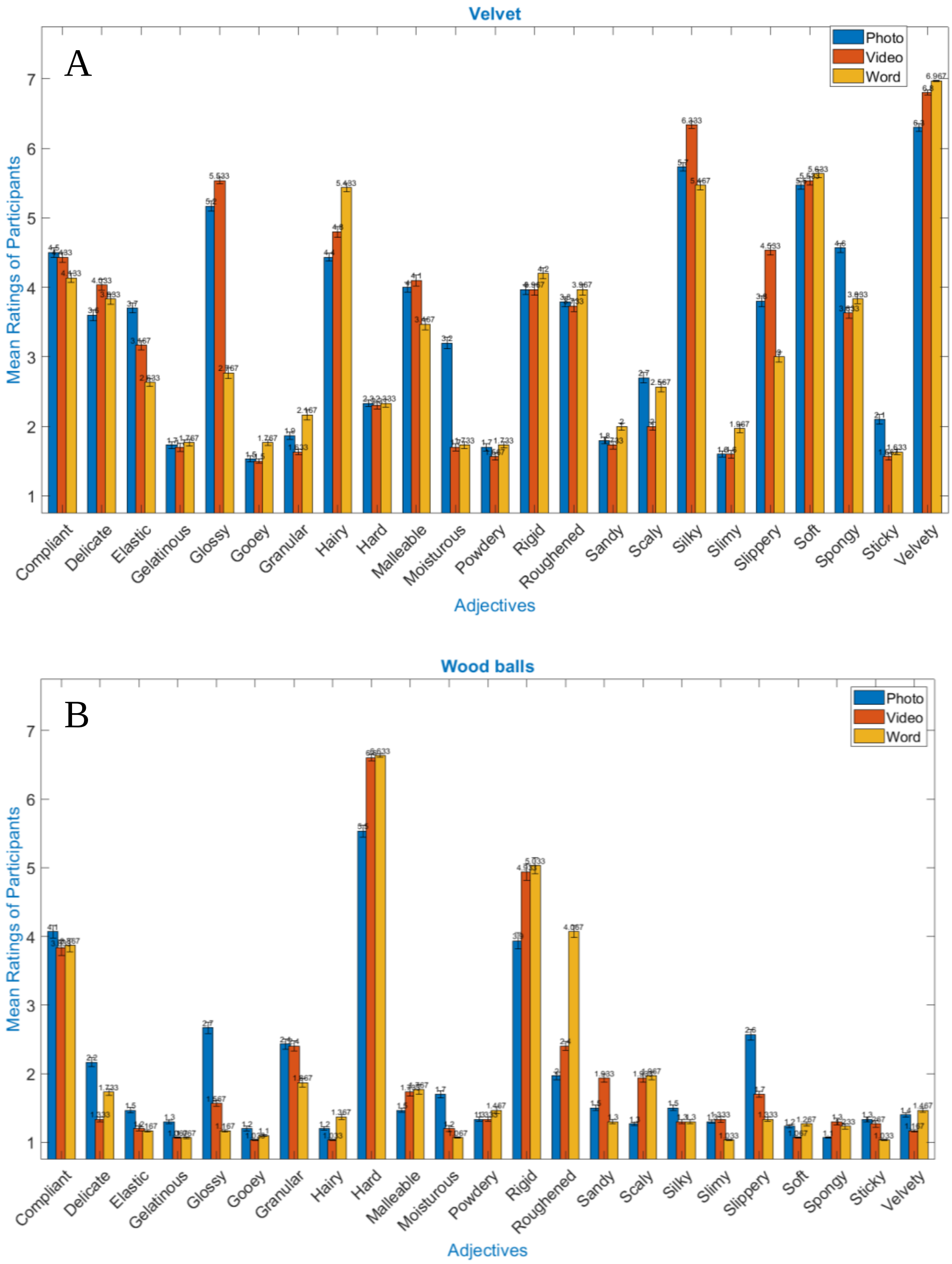


Figure G.25. Bar graphs of mean ratings of velvet (A) and wood balls (B). Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

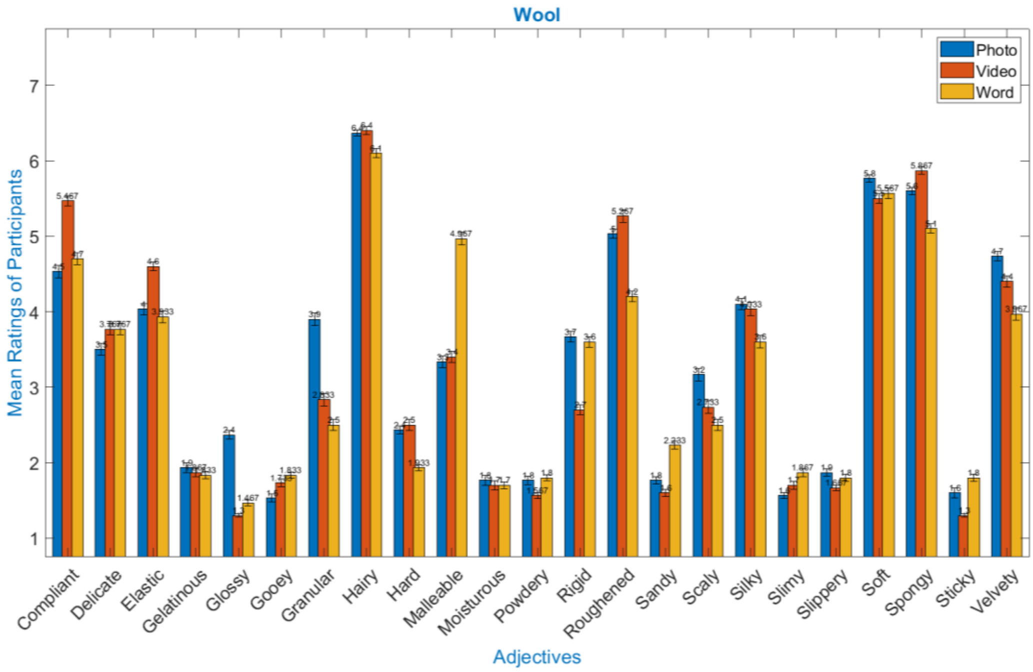


Figure G.26. Bar graphs of mean ratings of wool. Y-axis represents the mean ratings of participants, and X-axis represents the adjectives. Each bar depicts one condition as labeled in the legend.

C. TURKISH SUMMARY / TÜRKÇE ÖZET

BÖLÜM 1

GİRİŞ

Duyusal sistem, insanların nesnelerin şekli ve dokusu gibi özellikleri hakkında bilgi toplamasına ve çevreleriyle etkileşim halinde olmalarında kritiktir. Lederman ve Klatzky (1987) yürüttüğü bir çalışmada, bu keşif sırasında insanların tipik el hareketleri kullandıklarını gözlemlemişlerdir ve bu el hareketlerini Keşifsel Hareketler (KH) olarak adlandırmışlardır. Bu KH'lerin malzeme keşfi sırasında önemli bir rol oynadığını söylemek mümkündür. Hatta insanların, keşif sırasında kullandıkları KH'leri optimize ederek ilgilendikleri bilgiye erişmeye çalıştıkları görülmüştür (Kaim ve Drewing, 2011). Tüm bunlara ek olarak dokunsal algı, görme duyusunun yokluğunda insanların nesneleri tanımasında baskın bir rol oynamaktadır. Buna verilecek örnekler doğuştan görme engelli olan ancak buna rağmen derinlik algısına sahip Türk ressam Eşraf Armağan'dan başlayıp günlük hayattaki diğer örnekleri de içine almaktadır. Tüm bunlara dayanarak diyebiliriz ki dokunsal algının günlük hayattaki önemi vurgulanandan daha fazla ve karmaşıktır.

Dokunsal algı denildiğinde aktif ve pasif dokunmanın arasındaki fark vurgulanmalıdır. Gibson (1962)'ın da bahsettiği gibi pasif dokunma malzemenin elin yüzeyinde hareketiyle gerçekleşmektedir. Aktif dokunma ise keşfeden kişinin el ve kol hareketlerini içermektedir. Burada keşfeden kişi, somatosensoriyel sisteme ek olarak motor sistemden ve komutlardan da faydalanmaktadır. Çünkü motor sistemin yokluğunda bu keşifsel sürecin gerçekleşmesi mümkün olmamaktadır (Goodwin ve Wheat, 2008).

Beyindeki nesne kodlamanın malzeme özelliklerine bağlı boyutları olduğu gözlemlenmiştir (Hollin ve ark., 1993; Bergmann Tiest ve Kappers, 2006; Balota ve Coane, 2008; Okamoto ve ark., 2013; Kumar, 2021). Alanyazındaki çalışmaları derlendikleri makalelerinde Okamoto ve ark. (2013), 5 tane malzeme boyutu olduğunu göstermiştir. Ancak tüm bu çalışmalarda yumuşaklık tek bir boyut olarak alınmış ve uyumluluğun (compliance) psikolojik eşleniği olarak tanımlanmıştır. Ancak Dövencioğlu ve ark. (2018, 2019, 2022) yürüttüğü çalışmalarda, yumuşaklığın çok boyutlu olduğunu göstermiştir. Dövencioğlu ve arkadaşlarının (2022) yürüttüğü bir çalışma 4 yumuşaklık boyutu olduğunu ortaya koymuştur: Şekil Değiştirebilirlik, Akışkanlık, Taneciklilik ve Yüzey Yumuşaklığı (ve kontrol koşulu olarak Pürüzlülük). Ayrıca, insanların yumuşak malzemeleri keşfederken 8 farklı KH kullandıklarını gözlemlemişlerdir ve bu KH'lerin algısal yumuşaklık boyutlarıyla ilişkili olduklarını bulmuşlardır.

1.1. Yukarıdan Aşağı İşlemeler

Algı, duyulardan elde edilen bilgilerin yorumlanması, organize edilmesi ve kategorilendirilmesidir. Mekanoreseptörler ve kinestetik/propriyoseptif reseptörler, malzeme özellikleri hakkında bilgi toplamamıza yardım etmektedir. Ancak bu aşağıdan yukarıya işlemeler, algıyı tek başına açıklayamaz. Dikkat, bellek ve var olan bilgiler gibi yukarıdan aşağı işlemeler de devreye girerek insanların nesneleri ve çevresini anlamlandırmasına yardımcı olmaktadır (Wolfe, 1898; Hansen ve ark., 2006; Balcetis ve Dunning, 2010; Witzel ve ark., 2011; Metzger ve Drewing, 2019).

1.1.1. Tecrübeler ve Beklentiler

Bayes istatistiği, Helmholtz'un istatistiksel tekniklerinin değiştirilmiş ve genişletilmiş versiyonudur (Goldstein, 2010). Bayes teorisine göre, var olan bilgiler ve elde ettiğimiz veriler (örn., görsel ve dokunsal bilgiler) vereceğimiz kararları etkilemektedir. Başka bir deyişle, aşağıdan yukarı bilgiler farklı duyulardan bilgi toplamamızı sağlarken yukarıdan aşağı işleme bu bilgileri etkilemektedir ve böylece ikisi birlikte çalışarak verdiğimiz kararları şekillendirip belirsizliği en aza indirmeyi amaçlar (Kersten ve Yuille, 2003;

Kersten ve ark., 2004; Friston, 2005, 2010; Friston ve ark., 2006; Kilner ve ark., 2007a, b; Kveraga ve ark., 2007; Kersten ve Mamassian, 2009; Summerfield ve de Lange, 2014; Urgen ve Boyacı, 2019; Urgen ve Saygın, 2020).

Tecrübeler, var olan bilgiler ve beklentiler, dokunsal bellek üzerinde etkisi olan yukarıdan aşağı işlemelerden sayılmaktadır. Alanyazındaki çalışmalar dikkatin, içsel motivasyonların ve öğrenmenin bir nesneyi nasıl algıladığımızı etkilediğini göstermektedir (Tanaka ve ark., 2001; Witzel ve ark., 2011; Scocchia ve ark., 2013; Olkkonen ve Allred, 2014; Metzger ve Drewing, 2019). Ayrıca, malzeme algısında var olan bilgilerin etkisini araştıran çalışmalar da bunda algısal tecrübelerin ve semantik bilginin etkisi olduğunu ortaya koymaktadır (Abdel Rahman ve Sommer, 2008; Yee ve ark., 2013; Zoeller ve ark., 2019; Alley ve ark., 2020).

1.1.2. Bellek

Yukarıdan aşağı işlemelerden bahsederken belleğin günlük hayatımızda en çok etkisi olan faktörlerden biri olduğunu da vurgulamak gerekmektedir. Dokunsal bellek de günlük hayatta önemli bir yere sahiptir. Dokunsal bellek hem kısa süreli (Bliss et al., 1966; see also Gilson & Baddeley, 1969; Sullivan & Turvey, 1972; Watkins & Watkins, 1974; Miles, 1996; Gallace & Spence, 2008) hem de uzun süreli bilgi tutma kapasitesi sahiptir (Liu ve Song, 2008; Pensky ve ark., 2008; Hutmacher ve Kuhbandner, 2018; Ferreira ve ark., 2019; Metzger ve Drewing, 2019). Hatta uzun süreli dokunsal belleğin, görsel bellek kadar dayanıklı ve detaylı olduğu gözlemlenmiştir.

Alanyazından da görüldüğü üzere nesne ve malzeme algısı yukarıdan aşağı işlemelerden etkilenmektedir. Ayrıca, bu malzemelerle olan geçmiş tecrübelerimiz onlardan aldığımız duyusal sinyalleri (anlık bilgileri) etkileyebilmektedir. Bu tezin kapsamında bu bilginin rolü ve anlık duyusal sinyallerden farkı incelenecektir.

1.2. Kavramsal Bilgi

Semantik bellek, çok kapsamlı ve geniş bir depolama alanı olarak adlandırılmaktadır (Sperling, 1960; Tulving ve Pearlstone, 1966; Tulving, 1972). Depolanan bilgi, sözcük yapıları ve telaffuz ile alakalı bilgilere ek olarak nasıl göründüğü ya da hissettirdiğine dair duyusal bilgiler de barındırmaktadır (Balota ve Coane, 2008; Yee ve ark., 2011). Gauthier ve arkadaşlarının (2003) yürüttüğü bir çalışma bunu destekler niteliktedir. Buna göre görsel olmayan bilgi (örn., semantik) görsel bilgi ile etkileşime geçerek nesnelerin ayırt edilmesini kolaylaştırmaktadır.

Alanyazındaki çalışmalar da göstermiştir ki semantik bilgi beyinde hem görsel hem de dokunsal olarak kodlanıyor olabilmektedir ve algısal yargıları etkilemektedir. Böylece, malzeme özellikleriyle ilgili bilgi sağlayabilmektedir. Ancak bu bilginin ne boyutta olduğu bilinmemektedir. Bu tezin, kısmi olarak bu soruya cevap bulması amaçlanmaktadır.

1.3. Neden Dokunsal Algı Görsel Olarak Çalışıldı?

Alanyazından görüleceği üzere dokunsal bilginin doğasıyla, yani birden fazla duyusal kanallı mı yoksa bir kanaldan bağımsız (amodal) mı olduğuyla alakalı henüz ortak bir kanıya varılmamıştır (Aleman et al., 2001; Gallace & Spence, 2009). Ancak, birden fazla modaliteye bağlı olduğu yönünde destek sağlayan beyin görüntüleme çalışmaları mevcuttur (Lacey ve ark., 2007). Yapılan birçok çalışma göstermiştir ki görsel ve dokunsal algı, modaliteye özgü bazı özellikler barındırsalar da (örn., sıcaklık-dokunsal ve renk-görsel gibi) malzeme özelliklerine dair ortak boyutlara sahiptirler (Normal ve ark., 2004; Bergmann Tiest ve Kappers, 2007; Okamoto ve ark., 2013).

Malzeme özelliklerinin fotoğraf ve videolardan nasıl algılandığını araştıran çalışmalar da beyinde modaliteler arası bir temsilin söz konusu olduğunu göstermektedir. Buna göre, bazı çalışmalarda malzeme videolarının fotoğraflara göre daha gerçekçi yargılara varılmasını sağladığı gözlenmiştir (Wijntjes ve ark., 2019). Ve videolar gerçeğe ne kadar yakınsa malzemelerin dokunsal özellikleriyle alakalı yargılarda da o kadar iyi performanslar olduğu görülmüştür. Bunun gibi, Cavdan ve ark. (2021) dokunsal ve görsel algısal uzayların benzer olduğunu, ancak dokunsal ile dinamik görsel (video) bilginin arasındaki korelasyonun daha yüksek olduğunu bulmuşlardır. Bu da bizlere videonun gerçeği daha iyi temsil ettiğini göstermektedir. Ancak Xiao ve ark. (2016) çalışmalarında fotoğraf ve videoların benzer bilgiler açığa çıkardığını vurgulamıştır. Ancak Bouman ve arkadaşlarının (2013) da söylediği gibi fotoğraf ipuçları malzeme özellikleri hakkında bilgiler veriyor olsa dahi bunlar yanıltıcı olabilmektedir ve videolardaki mekanik ipuçları belirsizliği en aza indirerek daha kesin ve doğru sonuçlar doğurabilmektedir.

Alanyazından da görüldüğü gibi malzeme özellikleri farklı kanallar aracılığıyla iletilebilmektedir ve bu duyusal kanallar farklı derecelerde bilgiler açığa çıkarmaktadır. Bu fark insanların algısını etkileyebilmektedir. Bu yüzden, videolardan ve fotoğraflardan alınan bilgilerin farklı olup olmadığını anlamak önemlidir. Bu sebeple, bu tezin ilk kısmı bu farkı anlamaya odaklanmaktadır.

Son olarak, bu tez kapsamında kullanılacak olan optik ve mekanik ipuçlarının ne olduklarını açıklamak gerekmektedir. Optik ipuçları malzemelerin fotoğrafta nasıl göründüğü ile alakalıdır (örn., parlaklık ve transparanlık gibi). Optik özellikler, ışığın malzeme yüzeyiyle nasıl etkileştiğini bize göstermektedir (Schmid ve Doerschner, 2018). Mekanik ipuçları ise bizlere malzemenin güç altında nasıl bir davranış sergilediğini iletmektedir. Mesela, bir stres topuna baskı uyguladığında deforme olmaktadır ya da el kremini karıştırdığında el hareketiyle doğru yönde hareket etmektedir. Şekil ve devinim bilgisi mekanik özelliklerin önemli bir parçasıdır (Schmid ve Doerschner, 2018). İki malzeme, aynı optik özelliklere sahip olup farklı mekanik özellikler sergileyebilmektedir. Ayrıca, bu özelliklerin birbiriyle etkileşime geçerek malzemelerle alakalı bilgi sağladıklarını vurgulamak gerekmektedir.

1.4. Amaçlar ve Hipotezler

Bu tezde, var olan bilgilerle görsel ipuçlarının yumuşaklık algısı üzerindeki etkisi araştırılmıştır. Bunun için, günlük malzemelerden oluşan bir uyaran listesi hazırlanmış ve Türkçe'ye uyarlanmış yumuşaklıkla alakalı sıfatlar kullanılmıştır (Dövencioğlu ve ark., 2018, 2019).

Deney 1'de amaç, insanların farklı yumuşak malzemeleri nasıl algıladığını incelemektir. Temel araştırma sorusu, insanların dokunsal özelliklerle alakalı yargılarını var olan bilgilere mi yoksa anlık duyusal bilgilere mi dayandırdığıdır. Deney 1'in hipotezleri şöyledir: (1) mekanik ipuçları, malzeme özellikleri hakkında ilave bilgiler sağlayacaktır ve (2) mekanik ipuçlarının katkıları en çok yumuşaklık boyutuyla alakalı sıfatlarda ve mekanik sıfatlarda görülecektir (örn., Şekil Değiştirebilirlik boyutundaki sünger ve güç uygulanabilir gibi). Yukarıda bahsedilen alanyazınla doğru yönde şu sonuçlar beklenmektedir: (1) Yumuşaklığın çok boyutlu olması beklenmektedir (malzemeler ve sıfatlar bunu gösterecektir). Buna göre, 4 yumuşaklık boyutu açığa çıkması beklenmektedir: Şekil Değiştirebilirlik, Akışkanlık, Taneciklilik ve Yüzey Yumuşaklığı (Cavdan ve ark., 2021; Dövencioğlu ve ark. 2022). (2) Katılımcıların mekanik görsel ipucu koşulunda verdiği oylamaların diğer iki koşuldan (var olan bilgi koşulu ve optik görsel ipucu koşulu) daha yüksek olması beklenmektedir (Bouman ve ark., 2013; Cavdan ve ark., 2021). (3) Mekanik sıfatların (örn., sümüksü, kaygan ve güç uygulanabilir) mekanik görsel ipucu koşulunda daha yüksek oylamalar alması beklenmektedir.

Deney 2 ve 3'te temel hipotez, manipülasyon tekniğinin (diğer bir deyişler KH'lerin) malzeme özellikleri hakkında farklı bilgilerin açığa çıkaracağı ve bunun da malzeme özellikleri yargılarını etkileyeceği yönündedir. Dövencioğlu ve ark. (2022)'nın bulduğu sonuçlarla aynı doğrultuda (1) yumuşaklık boyutu ile ilişkili olan uyumlu KH'nin uyumsuz KH'ye kıyasla daha yüksek oylamalar alması beklenmektedir. Ayrıca, (2) bu oylama farkının KH ile aynı boyuttan seçilen malzeme ve sıfatlarda daha sık görülmesi beklenmektedir.

BÖLÜM 2

DENEY 1

2.1. Giriş

Geçmiş çalışmalar da göstermiştir ki var olan bilgiler malzeme özelliklerini nasıl algıladığımızı etkilemektedir (Abdel Rahman ve Sommer, 2008; Witzel ve ark., 2011; Metzger ve Drewing, 2019; Alley ve ark., 2020). Cavdan ve arkadaşlarının (2021) yürütmüş olduğu bir çalışmada farklı duyusal kanallar yardımıyla varılan ve malzeme özellikleri hakkında olan yargıların benzeştiğini göstermiştir. Alan yazından yola çıkarak yürüttüğümüz bu çalışmada, var olan bilgilerin ve mekanik ve statik görsel ipuçlarının malzeme algısı üzerindeki etkisi incelenmiştir.

2.2. Pilot Çalışma

Deney 1'den önce Qualtrics üzerinden yürütülen bir çalışmadır.

2.2.1. Katılımcılar

Üniversite öğrencisi 45 katılımcı vardır (41 kadın, Ort. Yaş = 24.31). Katılımcılara bilgilendirilmiş onam formu verilmiştir ve sözlü olarak da deneyi istedikleri zaman bırakabilecekleri söylenmiştir.

2.2.2 Uyaranlar ve Prosedür

Deney, online olarak Qualtrics'te yürütülmüştür. Ekranın başında günlük hayatta kullanılan malzemelerin ismi, fotoğrafı ya da videosu gösterilmiş ve altında da art arda sıralanmış 29 sıfat verilmiştir. Katılımcılardan bu sıfatları 1 ile 7 arasında, malzemeye uygunluğuna göre oylamaları istenmiştir.

Malzemeler ve sıfatlar, Dövencioğlu ve arkadaşlarının (2018, 2019) yürüttüğü çalışmalardakiler arasından seçilmiştir.

2.2.3. Sonuçlar

Cronbach alfa değerleri katılımcıların tutarlı oldukları göstermiştir. Temel Bileşen Analizi (TBA) 4 farklı yumuşaklık boyutu olduğunu ortaya koymuştur: Şekil Değiştirebilirlik, Akışkanlık, Taneciklilik ve Yüzey Yumuşaklığı (Cavdan ve ark., 2019, 2021; Dövencioğlu ve ark., 2018, 2019, 2022).

Varyans Analizi sonuçları fotoğraf ile kelime ve fotoğraf ile video koşulları arasında anlamlı farklı olduğunu göstermiştir. Ancak video ile kelime koşulları arasında anlamlı bir fark bulunmamıştır.

2.3. Deney 1

2.3.1. Yöntem

2.3.1.1. Katılımcılar

Orta Doğu Teknik Üniversitesinde öğrenci 90 katılımcı vardır (55 kadın, Ort. Yaş = 22.82). Katılımcılara bilgilendirilmiş onam formu verilmiştir ve sözlü olarak da bilgilendirilmişlerdir. Deney ortalama 45 dakika sürmüştür.

2.3.1.2. Uyaran ve Prosedür

Deney MATLAB R2021a üzerinde Psychtoolbox-3 kullanılarak tasarlanmıştır. Laboratuvar ortamında, bir bilgisayar ve fare kullanılarak yürütülmüştür.

Uyaran olarak günlük hayatta kullandığımız 25 malzemenin ismi, fotoğrafı ya da videosu kullanılmıştır. Fotoğraf ve videolar, laboratuvar ortamında araştırmacı tarafından çekilmiştir. Videoların uzunluğu 5 saniyedir ve videolarda araştırmacının eli KH’ler kullanarak bu malzemelerle etkileşime geçmektedir (Dövencioğlu ve ark., 2022).

Deneydeki farklı uyaran tipleri, gruplar arası deneysel koşulları ifade etmektedir: fotoğraf, kelime ve video. Buna göre, bu koşulların birinde olan katılımcı ekranın ortasında kelime fotoğraf ya da video görmüş ve üstte yazan sorudaki sıfatın bu malzemeyi 1 (hiç) ile 7 (çok) arasında ne kadar tanımladığını oylamıştır (örn., Bu malzeme ne kadar biçimlenebilir?).

2.3.2. Sonuçlar

Cronbach alfa değerleri, katılımcıların sıfatları tutarlı bir şekilde değerlendirdiğini ve bu sıfatların katılımcılarda benzer anlamlar uyandırdığını göstermiştir. Korelasyon matrisiyle oluşturulan ısı haritaları, katılımcıların video koşulunda daha tutarlı oylamalar verdiğini göstermiştir. 3 koşul için birleştirilmiş TBA sonuçları, 4 farklı yumuşaklık boyutu olduğunu ortaya çıkarmıştır: Şekil Değiştirebilirlik, Akışkanlık, Taneciklilik ve Yüzey Yumuşaklığı. Malzeme boyutlarıyla yapılan Karışık Desenli Varyans Analizi, koşul ana etkisi hariç diğer bütün ana ve ortak etkilerin anlamlı olduğunu göstermiştir. Analiz için Bonferroni düzeltmesi kullanılmıştır.

2.3.3. Tartışma

İlk hipotezin tersi yönünde, koşullar arasında anlamlı bir fark bulunamamıştır. Bunun sebebinin, Cavdan ve arkadaşlarının (2021) da belirttiği gibi algısal uzaylar arasındaki benzeşmeden kaynaklanıyor olabileceği düşünülmüştür. Bu duyusal kanallar, malzemelerle etkileşime geçerken topladıkları bilgileri bir kanaldan ötekine transfer edebilir ya da bu bilgileri farklı modaliteler birbiriyle paylaşabilir (Bergmann Tiest and Kappers, 2007; Baumgartner ve ark., 2013; Okamoto ve ark., 2013; Xiao ve ark., 2016; Wijntjes ve ark., 2019). Bu da bulduğumuz sonuçların sebebi olabilir. Ancak üçlü ortak etkiye baktığımızda malzeme ve sıfat çiftlerine özgü koşullar arasında farklar gözlemlenmiştir. Video ile kelime ya da fotoğraf koşulu arasında anlamlı farklara yol açan sıfatların mekanik özelliklerle bağlantılı oldukları görülmüştür. Fotoğraf ile kelime koşulları arasında farklar ise optik özellikleri tanımlayan (örn., parlak) sıfatlar içindir. Kelime koşulunda daha yüksek oylamalar alan sıfatlarda ise belirli bir örüntü gözlenmemiştir. Özetle sonuçlar, mekanik ipuçlarının avantajlarının boyutlara ve sıfatlara bağlı olarak kendini göstereceği hipotezini (2. Hipotez) destekleyen yöndedir.

BÖLÜM 3

DENEY 2 VE 3

3.1. Giriş

Lederman ve Klatzky (1987) çalışmasının üzerine araştırmacılar, KH'lerin yumuşak ve yumuşak olmayan malzemelerin keşfindeki ve bu malzemelerin özelliklerinin açığa çıkarılmasındaki etkilerini incelemişlerdir. Dövencioğlu ve ark. (2022) da yumuşaklık algısının çok boyutluluğunu ve KH'lerin bu boyutlarla ilişkisini inceleyen bir çalışma yürütmüştür. Sonuçlar 4 farklı yumuşaklık boyutu olduğunu göstermiştir: Şekil Değiştirebilirlik, Akışkanlık, Yüzey Yumuşaklığı ve Taneciklilik (kontrol koşulu olarak da Pürüzlülük). Ayrıca, insanların yumuşak malzemelerle etkileşime geçerken 8 farklı KH kullandıklarını ve bu KH'lerin belirli boyutlarla ilişkili olduğunu gözlemlemişlerdir.

3.2. Deney 2

3.2.1. Yöntem

3.2.1.1. Katılımcılar

Deney 2'de 30 katılımcı vardır (22 kadın, Ort. Yaş = 23.1). Katılımcılara bilgilendirilmiş onam formuyla beraber sözlü bilgilendirme yapılmıştır. Deney ortalama 20 dakika sürmüştür.

3.2.1.2. Uyaran ve Prosedür

Deney, MATLAB R2021b Psychtoolbox-3 kullanılarak tasarlanmıştır. Uyaran olarak, ilk deneyin sonuçları baz alınarak her boyuttan 2 malzeme seçilmiş (toplamda 8 malzeme) ve her bir malzemeden uyumlu ve uyumsuz birer KH kullanılarak 2 farklı video oluşturulmuştur. Uyumlu ve uyumsuz KH'ler Dövencioğlu ve ark. (2022) çalışması baz alınarak kararlaştırılmıştır. Ve bir KH, bir malzeme için uyumluyken diğeriyle uyumsuz olacak şekilde seçilmiştir. Katılımcıların görevi oluşturulan 16 videoyu sıfatların onu ne kadar tanımladığına göre oylamaktır (12 sıfat). Uyumlu ve uyumsuz KH'lerin kullandığı videolar farklı iki deneysel koşulu ifade etmektedir.

3.2.2. Sonuçlar

Varyans Analizi sonuçları, bütün ana ve ortak etkilerin anlamlı olduğunu göstermiştir. Ancak üçlü ortak etkiye bakıldığında hipotezlenen farkların gözlemlenmediği görülmüştür. Bunun KH seçiminden kaynaklanabileceğini ve ne kadar uyumsuz olursa olsun bu KH'ler bir malzeme boyutuyla ilişkili olduğu için malzeme özellikleri hakkında katılımcılara bilgi vermiş olabilir. Bunun karıştırıcı etki yaratmış olabileceğini düşündüğümüz için daha kontrollü uyaranlarla Deney 3 yürütülmüştür.

3.3. Deney 3

3.3.1. Yöntem

3.3.1.1. Katılımcılar

Deney 3'te 25 katılımcı vardır (16 kadın, Ort. Yaş = 25.32). Katılımcılar sözlü olarak bilgilendirilmiş ve bilgilendirilmiş onam formu imzalatılmıştır. Deney ortalama 20 dakika sürmüştür.

3.3.1.2. Uyaran ve Prosedür

Deney MATLAB R2021b Psychtoolbox-3 kullanılarak tasarlanmıştır. Uyaran olarak Sünger, Yün topları ve Kinetik kum hariç yeni malzemeler kullanılmıştır. Uyumlu KH'ler aynı bırakılmış, uyumsuz KH olarak da her bir malzeme için "Karıştırma (stirring)" kullanılmıştır. 8 tane malzemeden 16 video oluşturulmuş ve Deney 2'de kullanılan 12 sıfatın onları ne kadar tanımladığı oylanmıştır.

3.3.2. Sonuçlar

Varyans Analizi sonuçları bütün ana ve ortak etkilerin anlamlı olduğunu göstermiştir. Üçlü ortak etkilere bakıldığında hipotezlendiği gibi anlamlı koşul farkları gözlemlenmiştir. Bu farkların daha çok malzemeyle aynı boyuttan seçilen sıfatlarda olduğu görülmüştür. Bu da deneyin hipotezi kısmi olarak desteklediği yönündedir.

3.3.3. Tartışma

Deney 2 ve 3'te 4 yumuşaklık boyutuyla ilişkili olan sıfatlar için aynı boyuttan seçilen malzemelerin, uyumlu koşulda daha yüksek oylamalar alacağını hipotez etmiştik. Deney 2'de hipotezimizin tersi yönünde bulgular elde edilmiştir. Örneğin, kinetik kum viskoelasik özellikler göstermiştir. Bunun da malzemenin doğasıyla ilişkili olduğu düşünülmüştür. Deney 3'te uyumsuz KH olarak kullanılan karıştırma hareketinin akışkanlıkla alakalı özellikleri açığa çıkarabileceği düşünüldüğü için akışkan malzemelerde bir fark gözlemleneceği hipotez edilmemiştir. Ancak, bal için vıcık vıcık sıfatı iki koşul arasında anlamlı bir fark açığa çıkarmıştır. Bunun da akışkan malzemelerle ilişkili olan çekme (pulling) hareketinin oldukça bilgilendirici bir KH olmasından kaynaklanıyor olabileceği düşünülmüştür. Deney 2'den farklı olarak kinetik kum yalnızca elastik özellikler sergilemiştir. Malzemenin doğasından dolayı karıştırma hareketinin yeterince bilgilendirici olmadığı düşünülmüştür. Son olarak da yüzey yumuşaklığı boyutu için öngörülen farklar bulgularda gözlemlenmemiştir. Karıştırma hareketi ile yüzey yumuşaklığı boyutuyla korele olan okşama hareketinin birbirine benziyor oluşundan kaynaklandığı düşünülmüştür. Çünkü iki KH de malzeme ve onun yüzeyiyle daimî bir temas gerektiriyor ve bu da benzer dokunsal yargıların açığa çıkmasına sebep olmuş olabilir.

BÖLÜM 4

GENEL TARTIŞMA

4.1. Genel Bakış

Bu tez, var olan bilgilerin ve görsel ipuçlarının yumuşaklık algısı üzerindeki etkisini incelemeyi amaçlamaktadır. Bu doğrultuda araştırma sorularımız şöyledir: (1) "Var olan bilgilerin ve görsel ipuçlarının algılanan yumuşaklık üzerindeki rolü nedir?", (2) "Mekanik ipuçlarının malzeme özellikleri hakkında ilave bilgiler açığa çıkarmakta mıdır (örn., ne kadar vıcık vıcık)?" ya da başka bir deyişle "Mekanik ipuçlarının optik özelliklere ya da var olan bilgilere avantajları var mıdır?", (3) "Bu farklar sıfat ve boyuta özgü olarak açığa çıkmakta mıdır?" ve (4) "Farklı KH'ler malzeme özellikleri hakkında farklı bilgiler açığa çıkarır mı?". Bu doğrultuda Deney 1'de katılımcılar günlük hayatta kullanılan malzemelerin isimlerini, fotoğraflarını ya da videolarını yumuşaklıkla alakalı sıfatlar bazında oylamıştır. Deney 2 ve 3'te ise kullanılan farklı KH'lerin farklı malzeme özellikleri ve boyutlarıyla ilişkili olup olmadığı araştırılmıştır. Burada da 8 farklı malzemeyle bir uyumlu bir uyumsuz KH kullanarak oluşturulan 16 video, 12 tane yumuşaklıkla alakalı sıfatın onları ne kadar tanımladığına göre oylanmıştır.

4.2. Deney 1'in Sonuçları için Tartışma

Deney 1'de mekanik ipuçlarının var olan bilgilere ve optik özelliklere kıyasla avantajları olup olmadığını araştırılmıştır. Sonuçlar, koşullar arasında anlamlı bir ana etki göstermese de malzeme ve sıfat çiftleriyle ilişkili anlamlı farklar bulunmuştur. TBA sonuçları, literatürle doğru yönde 4 farklı yumuşaklık boyutu açığa çıkarmıştır: Şekil Değiştirebilirlik, Akışkanlık, Taneciklilik ve Yüzey Yumuşaklığı (Cavdan ve ark., 2021; Dövencioğlu ve ark., 2022).

Cavdan ve arkadaşlarının (2021) yürüttüğü çalışmada da olduğu gibi üç farklı oylama farkı vardır. Birincisi, video ve fotoğraf koşulu arasındadır. Cavdan ve arkadaşlarının (2021) bulduğu sonuçların aksine, burada videolar daha yüksek oylamalar almıştır. Bu oylamalar bir sıfat hariç (Şekil Değiştirebilirlik için esnemez) mekanik özelliklerle ilişkili sıfatlar içindir (örn., esnek, yapışkan ve kaygan). Her ne kadar fotoğraflar malzeme özellikleri hakkında bilgiler açığa çıkarıyor olsa da bir malzemenin fotoğrafını görmek ona benzer olan başka malzemelerle alakalı bilgileri hatırlatacağı için yanıltıcı olabilir (Bouman ve ark., 2013, Wijntjes ve ark., 2019). Sonuç olarak, hipotezimizi doğrulayan yönde bir sonuç bulunmuştur. İkinci grup fark, kelime ile fotoğraf koşulları arasındadır. Parlak sıfatı iki yumuşaklık boyutu için fotoğraf koşulunda daha yüksek oylamalar almıştır. Optik özellikler fotoğrafta daha baskın olduğu için bu sonuç hipotezle doğru yöndedir. Üçüncü grupta ise video ile kelime koşulu arasında farklar vardır. Esnek ve sümüksü gibi mekanik özellikler ile nemli ve parlak gibi optik özellikler açığa çıkaran sıfatlar video koşulunda daha yüksek oylamalar almıştır.

Alanyazındaki çalışmaların da belirttiği gibi var olan bilgiler zamanla malzemelerin dokunsal, görsel ve anlamsal özellikleriyle alakalı konseptler oluşturuyor olabilir. Bu da bir malzemeyi görmeden ya da ona dokunmadan malzemenin optik ve mekanik özellikleri hakkında yargılarda bulunmamıza yardımcı olabilir. Ancak bir konseptin işlemeye hazırlanması diğer konseptleri de aktive edebilir ve yargılarımızda yanıltıcı ya da karıştırıcı bir etki oluşturabilir.

4.3. Deney 2 ve 3'ün Sonuçları için Tartışma

Tezin ikinci kısmında, insanların malzemelerle etkileşime girme şeklinin algılarını ve yumuşaklık yargılarını nasıl değiştirdiği incelenmiştir. Uyumlu ve uyumsuz KH'lerle oluşturulan videolar katılımcılar tarafından oylanmıştır. Deney 2'de hipotezi desteklemeyen yönde sonuçlar bulunmuştur. Buna ek olarak, kinetik kum viskoelastik özellikler sergilemiştir. Bu sonuçların malzemenin doğası gereği hem katı hem de akışkan olmasından dolayı ortaya çıktığı düşünülmektedir. Diğer yandan, hipotezle aynı yönde sonuçlar bulunmamış olması da KH seçiminden kaynaklanmış olabilir. Bu deneyde kullanılan bütün KH'lerin malzeme boyutlarından biriyle ilişkili olduğu daha önce gösterilmiştir (Dövencioğlu ve ark., 2022). Bu tezde, bir boyut için uyumlu olan KH, diğeri için uyumsuz olarak kullanılmıştır ve uyumsuz olsa dahi bu KH, belli malzeme özellikleri hakkında bilgi verdiği için karıştırıcı bir etki yaratarak sonuçları etkilemiş olabileceği düşünülmektedir.

Deney 3'te ise Deney 2'nin sonuçlarının KH seçiminden kaynaklanmış olabileceğini test etmek amaçlanmıştır. Uyumsuz KH "karıştırma" olarak seçilmiştir ve akışkanlıkla alakalı özellikleri açığa çıkarabileceği düşünüldüğü için akışkanlık boyutunda anlamlı sonuçlar bulmak hipotezlenmemiştir. Ancak bal için vıcık vıcık sıfatında anlamlı farklar bulunmuştur. Bu da uyumlu KH olan "çekme" hareketinin daha bilgilendirici olmasından kaynaklanıyor olabilir. Ayrıca, kinetik kum yalnızca elastik özellikler sergilemiştir. Deney 3'te kullanılan KH karıştırma iken Deney 2'de bu hareket çekme hareketidir. Bu da bize çekme hareketinin akışkanlık özellikleriyle alakalı daha çok bilgi verdiğini söylüyor olabilir. Yüzey yumuşaklığı boyutunda öngörülen bütün farklar gözlenmemiştir. Bunun uyumlu KH "okşama" hareketi ile "karıştırma" hareketinin benzerliğinden kaynaklandığı düşünülmektedir. İkisi de malzeme yüzeyiyle daimî bir etkileşim gerektirdiği için benzer bilgiler açığa çıkarmış olabilir. Sonuç olarak, hipotezin kısmi bir şekilde desteklendiği söylenebilir.

4.4. Kısıtlamalar ve Gelecek Çalışmalar

Deneydeki ilk kısıtlama, gündelik malzemelerin kullanılması, dolayısıyla var olan bilgilerin etkisinin elenememesidir. Bunun da sebebi şaşırtıcı ya da tanınmayan malzemelerin bulunmasının zor olmasıdır. Gelecek çalışmalarda günlük hayatta karşılaşılmayan malzemelerle ile günlük hayatta kullanılan malzemeleri beraber kullanarak var olan bilgilerin etkisini daha net inceleyebiliriz. Hatta katılımcılara deney öncesinde malzemeleri ne kadar tanıdıklarına dair kısa bir anket yaparak bilgi seviyesini eşleştirmeye çalışıp 2 farklı koşula dağıtabiliriz. İkinci kısıtlama da Deney 1'in süresinin uzun olmasıdır. Bu durum katılımcıların odaklanmasını zorlaştırmış ve yanıtlarını etkilemiş olabilir. Gelecekte yürütülecek çalışmalarda uzun olanlar iki kısma bölünerek bunun önüne geçilebilir. Ve yine gelecek çalışmalarda, malzemenin fotoğrafı yerine bir elin malzemeyi manipüle ederken çekilmiş fotoğrafı video ile karşılaştırılıp mekanik özellikler arasında anlamlı sonuçlar açığa çıkarıp çıkarmayacağına bakılabilir.

4.5. Sonuç

Özetle, mekanik ipuçlarının videoda daha yüksek oylamalar açığa çıkaracağı hipotezi, koşullar arasında ana bir fark bulunmadığı için desteklenmemiştir. Ancak bu farkın, mekanik sıfatlar için videodan diğerlerinden daha yüksek olacağı hipotezi kısmen desteklenmiştir. Buna ek olarak, koşullar arasındaki farkların malzeme boyutu ve sıfat ile ilişkili olacağı hipotezi desteklenmiştir. Son olarak, malzemelerle etkileşime girerken kullanılan KH'lerin katılımcıların yargılarını değiştirebileceği hipotez edilmiştir. Deney 2 ve 3'in sonuçları bu hipotezi kısmi olarak desteklemiştir.

Bildiğimiz kadarıyla bu tez, var olan bilgilerin ve görsel ipuçlarının algılanan yumuşaklık üzerindeki etkisini karşılaştıran ilk çalışmadır. Malzeme algısıyla ilgili el hareketlerini incelemek gelecekte yapılacak çalışmalarla internet alışverişinden robotiğe kadar birçok alana katkı sağlama potansiyelindedir.

D. THESIS PERMISSION FORM / TEZ İZİN FORMU

(Please fill out this form on computer. Double click on the boxes to fill them)

ENSTİTÜ / INSTITUTE

Fen Bilimleri Enstitüsü / Graduate School of Natural and Applied Sciences	☐
Sosyal Bilimler Enstitüsü / Graduate School of Social Sciences	☒
Uygulamalı Matematik Enstitüsü / Graduate School of Applied Mathematics	☐
Enformatik Enstitüsü / Graduate School of Informatics	☐
Deniz Bilimleri Enstitüsü / Graduate School of Marine Sciences	☐

YAZARIN / AUTHOR

Soyadı / Surname : KILIÇ
Adı / Name : Fatma
Bölümü / Department : Psikoloji / Psychology

TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English):

THE ROLE OF PRIOR KNOWLEDGE AND VISUAL CUES ON PERCEIVED SOFTNESS

TEZİN TÜRÜ / DEGREE: **Yüksek Lisans** / Master ☒ **Doktora** / PhD ☐

1. **Tezin tamamı dünya çapında erişime açılacaktır. /** Release the entire work immediately for access worldwide. ☒
2. **Tez iki yıl süreyle erişime kapalı olacaktır.** / Secure the entire work for patent and/or proprietary purposes for a period of **two years**. * ☐
3. **Tez altı ay süreyle erişime kapalı olacaktır.** / Secure the entire work for period of **six months**. * ☐

***** *Enstitü Yönetim Kurulu kararının basılı kopyası tezle birlikte kütüphaneye teslim edilecektir. /*
A copy of the decision of the Institute Administrative Committee will be delivered to the library together with the printed thesis.

Yazarın imzası / Signature .... **Tarih** / Date ....
(Kütüphaneye teslim ettiğiniz tarih. Elle doldurulacaktır.)
(Library submission date. Please fill out by hand.)

Tezin son sayfasıdır. / This is the last page of the thesis/dissertation.