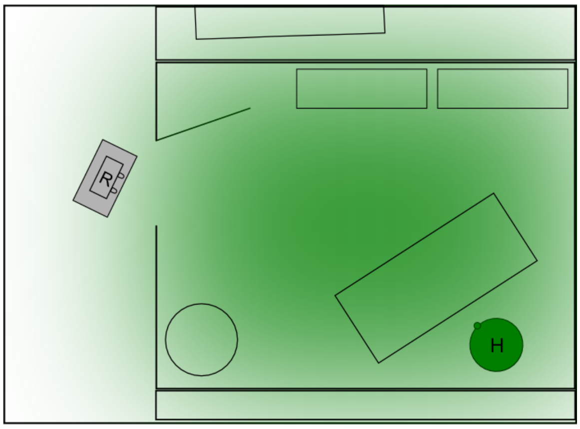
Robotic Infringement of Human Territories in Office Environments

Bachelor Thesis
[Wissens- und Sprachverarbeitung]



Kim Reichert

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9reicher@informatik.uni-hamburg.de
Fachbereich Informatik, Mensch-Computer-Interaktion
Matr.-Nr. 6144830
Fachsemester 8

Betreuer: Prof. Dr. Christopher Habel / Felix Lindner

Abstract

As robots begin entering our daily life, determining and implementing socially acceptable behavior of robots gains importance. Among other factors, robots will need to improve their use of social space (proxemics) around humans to improve the human-robot interaction. In this thesis, I examine whether and how people perceive territory intrusion by robots. The workplace was chosen as the environment and the office represents the social territory.

The study design consisted of a thought experiment where 20 participants (10 female) between the ages of 23 and 64 listened to an audio text. Independent variables were the type of activity that the robot was executing and the presence of the owner. The audio-text contained six scenarios where a robot entered the imaginary office of the participant, executing a different activity in each scenario. Presence differed within subjects (for three scenarios they were described as present) and between subjects (e.g., when group A was present in one scenario, group B was not).

The results suggest that humans do perceive robotic territory intrusion. Significant influence of the robot's activity could be found within participants. Also, significant interaction was found for presence of the territory owner and activity. Finally, there was a significant effect of age. Gender did not appear to have any significant influence.

A possible task for consecutive studies could be the implementation of territory recognition in robots to improve the social behavior.

Keywords: Human-robot interaction, proxemics, socio-spatial behavior, territory infringement, thought experiment, electrodermal activity

Kurzfassung

Es ist absehbar, dass Roboter zunehmend zum Teil unseres Alltags werden und immer öfter mit Menschen in Interaktion treten. Umso mehr gewinnt ihr soziales und sozial-räumliches Verhalten (Proxemik) an Bedeutung. Zu diesem sozialen Verhalten gehört auch die Rücksichtnahme von Robotern auf menschliche Territorien. Die hier vorgelegte Arbeit sollte einen Beitrag leisten zur Beantwortung der Frage, ob und wie Menschen das Eindringen von Robotern in ihr Territorium wahrnehmen und bewerten. Ausgewählt als Umfeld der Untersuchung wurde der Arbeitsplatz. Zum Territorium im sozialwissenschaftlichen Sinne bestimmt wurde das eigene Büro.

Der Versuchsaufbau bestand aus einem Gedankenexperiment, bei dem Versuchspersonen per Audiotext eine Geschichte vorgelesen wurde. An dem Experiment nahmen 20 Versuchspersonen teil, darunter 10 Frauen. Das Alter der Versuchspersonen lag zwischen 23 und 64 Jahren. Im Rahmen des Gedankenexperiments fuhr ein Roboter in sechs verschiedenen Szenarien in das imaginative Büro der Versuchsperson. Der Roboter führte dabei jeweils eine andere Aktivität aus. Dies repräsentierte die erste unabhängige Variable - Aktivität. Die zweite Variable bestand in der Anwesenheit bzw. Abwesenheit des Büroinhabers. Die Versuchspersonen wurden dafür in zwei Gruppen aufgeteilt, bei denen sich Anwesenheit bzw. Abwesenheit je Aktivität voneinander unterschieden, ausserdem wurde innerhalb der Versuchspersonen die Anwesenheit variiert (3 mal anwesend, 3 mal abwesend). Während des Experiments wurde die elektrodermale Aktivität der Versuchspersonen gemessen. Im Anschluss wurden den Versuchspersonen zwei Fragebögen vorgelegt.

Die Auswertung der Untersuchung zeigt, dass Menschen es als Störung empfinden, wenn ein Roboter in ihr Territorium eindringt. Das Ausmaß dieses Empfindens hängt jedoch signifikant von den beiden Variablen der Aktivität des Roboters und von der Präsenz des Büroinhabers ab. Die Untersuchung hat darüber hinaus gezeigt, dass das Alter einen Einfluss auf das Ausmaß des Störungsempfindens hat, während das Geschlecht keine signifikante Rolle zu spielen scheint.

Nachfolgende Aufgabe weiterer Untersuchungen könnte sein, die Ergebnisse in größerem Umfang zu bestätigen und Lösungsansätze zu finden, wie Territorien durch Roboter erkannt und berücksichtigt werden könnten.

Stichwörter: Mensch-Roboter-Interaktion, Proxemik, sozial-räumliches Verhalten, Territorien, Gedankenexperiment, elektrodermale Aktivität

Contents

1. Introduction

To interact in a socially acceptable and comfortable way with humans, robots need to be aware of the social rules that dictate many human behaviors. In the field of human-robot interaction (HRI) and social robotics in general, one possible approach to improve interaction is to use concepts from psychology and social science as a basis. The theory of personal space developed by Hall (Hall, 1969) is one such concept, which models the social rules of human-human interaction (HHI), and has been implemented in robot systems in order to improve their social behavior (Nakauchi and Simmons, 2002; Kessler et al., 2011; Kirby et al., 2009). This concept concerns itself mainly with face-to-face interaction and different classifications of distances (or 'zones') that define differing adequate behavior. However, in daily life there are many more social rules and conventions that influence human behavior which should also be incorporated by robots.

Lindner and Eschenbach (2011) present five different types of social spaces that conceptualize different dimensions of social rules. Apart from personal space, they introduce mereopotological structures for penetrated space, activity space, affordance space, and territory space. This last social space is a concept which, unfortunately, is not as well represented in HRI literature as are the other three social spaces. Territory space describes the spatial areas where certain rules apply concerning the access of and the behavior in that area. Following Goffman (1971) they find that "territory spaces are constituted by claims asserted by groups of agents" (Lindner and Eschenbach, 2011, p. 294), and there is some notion of possession or exclusive usage connected with it. In other words, some social groups (be that scientist, hotel guests, pedestrian, or friend) have access to a territory (laboratory, parking space, sidewalk, seat at the cafeteria table) and can execute certain behaviors (work in it, park their car there, walk on it, sit on it). Altman (1975) distinguishes three kinds of territory spaces: primary, secondary and public. Especially secondary space, which can be temporary and can be found at locations such as the workplace, represents environments where service robots might be employed in the future.

1.1. Motivation

Many studies from the field of HRI have demonstrated that humans become aware of their own personal space when robots come too close to them (Kulic and Croft, 2005; Okita et al., 2012). With this knowledge, the robot's behavior can be modified to improve comfortable and natural interaction with humans. For instance, using the concept of personal space, the robot can navigate in a more natural manner, without crossing personal spaces of other humans (Kirby et al., 2009). In a similar way, knowledge of activity spaces can be used to improve interaction. For example, to help a robot join a group of people involved in conversation in a socially acceptable manner (Althaus et al., 2004). These existing approaches are a first step in the modification of the robots behavior, but many steps need to be done to improve human-robot interaction.

As will be demonstrated in the following chapter (2) the concept of territory space includes several aspects that are of a similar nature to those from personal space; a possible conclusion is that humans may also become aware of their territory spaces when robots enter or interact in them. Robotic intrusion could happen, for instance, when the personal robot of an acquaintance enters the private bedroom of the house owner during a visit, when a cleaning robot moves personal belongings in a study hall from one table to another without permission, or when a robot enters someone's personal office at work without knocking. These incidences could prove annoying or uncomfortable for the concerned party and prevent successful interaction between the human and robot in the future. Furthermore, additional factors that could influence a humans perception on robotic intrusion should be considered, as well. Contrary to personal space, a territory space can be intruded while the owner is absent. It could be of interest, whether presence of the owner has an influence on his/her perception of intrusion. Especially, since this factor can not exist for personal space intrusion it should and will be considered in this study.

To conclude, in this thesis the circumstances under which humans perceive territory spaces with respect to robots are examined and evaluated. Results show that the consideration and further investigation of human territory spaces in HRI are necessary.

1.2. Study Design and Hypotheses

Approaches from literature of social psychology and HRI will be used to measure the perception of territory spaces and territory space violations with respect to robots. Often, these approaches consist of breaching a territory or breaking a social norm in order to prove its existence. In a similar way, I will provoke the intrusion into territory space, i.e., the breach of social rules that come with territory by robots, and measure participant's reactions.

Assuming that humans will perceive their territory spaces the same way with robots as they do with humans, I presume the following hypotheses:

- H1: Humans will perceive the intrusion of a robot into their territory space.
- H2: Depending on the activity the robot is executing, the intrusion will be felt more strongly
- H3: Depending on the presence of the human, the intrusion will be felt more strongly

Referring to studies of similar nature from HRI and social psychology and keeping my hypotheses in mind, I developed my own study design and instruments including two questionnaires. Based on this design, I prepared and conducted a study that involves a scenario where a robot enters the territory of the subject. This scenario was written as a text, recorded on audio and presented to my participants. I evaluated the results of this study and discuss the outcome and possible future prospects in the last chapter.

In the following chapter, related concepts such as activity space, personal space and territory space will be introduced and important terms defined for later use. Subsequently, a short overview on the related work will follow, introducing papers from HRI where different social spaces have been studied and implemented into the robot's behavior. Thereafter, I will describe the study design before presenting and evaluating the results. Finally, a discussion about the results will follow where I conclude my study and present suggestions and improvements for future studies.

2. Territory and Other Social Spaces

In this chapter, I will shortly introduce the concepts of activity space and personal space. Then, I will define the term territory space and related aspects, before comparing territory space and personal space for a better understanding and clear distinction of the two concepts.

2.1. Activity Space

The activity space is a socio-spatial concept that is constituted when people execute an action. Or in other words, "Activity spaces are constituted by activities performed by groups of agents"(Lindner and Eschenbach, 2011, p.293). Lindner and Eschenbach see Adam Kendon's model of so-called F-formations as one way to describe this concept (Kendon, 1990). F-Formations are social patterns that can be observed between people who hold conversations. They consist of three different regions that together build the F-formation. The o-space is a transactional region where any real interaction (from the activity) takes place. Surrounding this region and including the participants is the p-space, and finally enclosing the activity and working as a buffer zone is the r-space.

Kendon distinguishes three types of F-formations (see figure 2.1): the side-by-side formation where people stand next to each other, the vis-a-vis formation where people are positioned opposite of each other, and the L-shape formation. Here, people stand perpendicular to each other, often relating to an external object, e.g a painting.

As will be demonstrated further in Chapter 3, humans and robots also can enter into activity spaces, for example when communicating about an object. If the robot respects and knows that humans prefer and use the spatial patterns during an activity, it can respect and support them. Furthermore, it can avoid disturbing or entering into an activity space, when it recognizes that an activity is taking place. For instance, not driving in front of a person watching TV. Therefore, the knowledge about such a concept can be valuable to improve interaction.

2.2. Personal Space

Edward T. Hall was one of the first authors to describe a phenomenon of social behavior that occurs around and between humans and has a distinct socio-spatial note. He termed this phenomenon *proxemics* to describe the "...interrelated observations and theories of man's use of space as a specialized elaboration of culture" Hall (1969).

Furthermore he developed a theory on a subconept of proxemics that is widely known as *personal space*. In his book "The Hidden Dimension", Hall distinguishes four different distance zones, that constitute different social zones of the personal space: intimate distance, personal distance, social distance and public distance (Hall, 1969) (see figure 2.2).

Depending on the distance, different kinds of interactions between people are possible. For example, at intimate distance, very close interaction such as hugging or touching takes place. Vision of the other person is blurred, and body heat and odors can be perceived. At personal distance, face-to-face conversation is possible. At social distance, touching is no

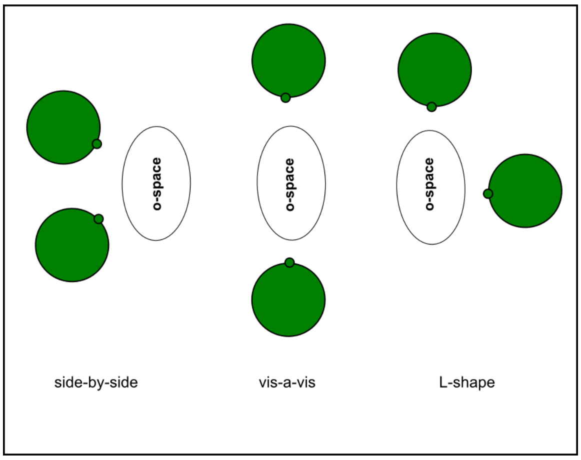


Figure 2.1.: Kendon's three types of F-Formations. Humans enter into these formations with other humans, as well as robots during interaction.

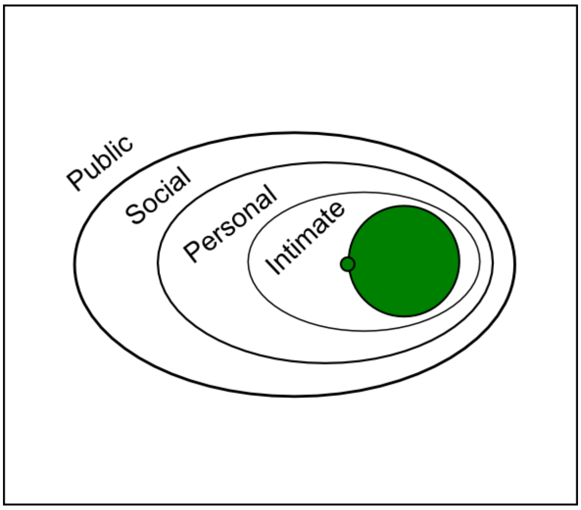


Figure 2.2.: This figure represents Hall's personal space with it's four zones from his book 'The hidden Dimension' (Hall, 1969)

longer to be expected. Normal, rather impersonal interaction takes place at this distance, for example between customer and shop assistant. Public distance is the distance which is kept between strangers. No interaction is necessary; if it takes place the voice is loud or even amplified and gestures and body stance need to be exaggerated.

In summary, personal space is a socio-spatial concept that explains different social and functional behaviors taking place between people, which depends on the distance, situation and relationship of those people. It can be used to describe and model human-human interaction as well as human-robot interaction.

2.3. Territory Space

According to the website of Oxford Dictionaries[1] the term territory has three different meanings.

[1] http://oxforddictionaries.com/definition/english/territory?q=territory, date: 21.05.2013

It can imply "an area of knowledge, activity or experience". For example, unknown territory can refer to a field of (in-) expertise. Also, the term describes "an area of land under jurisdiction of a ruler or a state", which has a distinct spatial and possessive note. In this context, territory can refer to either an area defended by an animal (biological explanation), a place with a specific characteristic such as a woodland territory (geological explanation), or finally, an area "in which one has certain rights or for which one has certain responsibility" (socio-psychological explanation). It is this last definition that best matches the different definitions of territory space from the social literature.

So far, territory is a purely *functional* concept. From the perspective of social psychology, however, many references to a *social* aspect of territory can be found. Delany sees a territory as a "bounded social space that inscribes a certain sort of meaning onto defined segments of the material world" (Delaney, 2008, p. 14). He distinguishes between inside and outside of the territory. Similarly, Altman finds that territories are "variable in physical size, functional complexity and location" (Altman, 1975, p. 108). This confirms some kind of spatial form for a social territory not unlike the personal space.

However, contrary to personal space, territory space belongs to a certain location, or, as Altman puts it "involves use of places and objects" (Altman, 1975, p. 105). Following this, territory space is relatively stationary and removed from the immediate person, whereas the personal space always moves with the person it belongs to (Sommer, 1959; Altman, 1975). It is important to note that, although territory space can belong to a certain location (e.g. an office, or a bedroom) it does not necessarily hold the exact same form.

Furthermore, territory spaces can last some period of time (Delaney, 2008). Thus, a territory can be long-lasting or temporary. Goffman (1971) calls territories either *fixed* or *situational*. Whereas fixed territories have an ongoing owner, sometimes even supported by law (e.g. land-owner), situational territories such as park benches or restaurant-tables entail the problem to determine when a claim to a territory begins and when it ends (Goffman, 1971). Goffman gives a very nice collection of well-phrased examples for situational territories, and should be consulted for further research of the topic [2].

Territories can belong to an individual or a group of persons, in contrast to personal space, that only belongs to one person (Altman, 1975). For example, a pick-nick table in a park 'belongs' to all members of the family that has laid claim to it.

Finally, territories can be defined and identified by some form of markers, for example fences or signs notifying others of the existence and sometimes size of the territory (Delaney, 2008; Altman, 1975).

Summarizing the above-mentioned perspectives on (social) territory, we can conclude a characterization that I will refer to, from now on, as territory space (or territory):

> **A territory is a spatially bounded region (or object), defined by some kind of markers, owned by a person or social group and lasting for a certain period of time.**

2.3.1. Types of Territories

In the literature, approaches exist to distinguish different types of territories based on varying characteristics. For example, according to how central a territory is to its owner,

[2] "[A territory space is a] well-bounded space to which an individual can lay temporary claim, possession being on an all-or-none basis. A scarce good will often be involved, such as a comfortable chair, a table with a view, an empty cot, a telephone booth. In the main, [territory spaces] are fixed in the setting, although, for example, at beaches devices such as large towels and mats can be carried along with the claimant and unrolled when convenient, thus providing a portable territory space" (Goffman, 1971, pp. 32-33).

Table 2.1.: Summary of three Territory Types

	Primary	Secondary	Public
Description	Rather Permanent	Less permanent	Very temporary ownership
Examples	Home, car, room in a hospital	Office, waiting-area, regulars table	Beach Chair, telephone-booth, park bench

three different territories can be differentiated (following Altman) and for later purpose these shall be summarized shortly. See table 2.1 for an overview.

Primary: Primary territories are those most central to the owner. They are usually owned and used exclusively by them, on a daily basis. They are rather permanent and easy to identify. A typical example is the home. Other places such as one's car can count as primary territories as well. The invasion of a primary territory by somebody not invited can unsettle a person's confidence and feel like an intrusion upon their privacy. This can lead to strong emotional reactions.

Secondary: These territories are often owned by groups of people, such as club-members, regulars in a bar, or working colleagues. The boundaries of secondary territories are less visible and rather unclear, and ownership is less permanent. As Altman puts it: "..., secondary territories often have unclear rules regarding their use and are susceptible to encroachment by a variety of users" (Altman, 1975, p. 117). They can be accessed by everybody, but there is still some form of control by the owners. Examples are a restaurant-table of a regular, hallways in an apartment building of the residents, the waiting area for patients, or a working area for a work group. Typical markers are locked or closed doors, name signs or personal objects such as a photo frame on a desk.

Public: "Public territories have a temporary quality, and almost anyone has free access and occupancy rights ... as long as the users follow some social rules and norms" (p.118). Beaches, playgrounds, parks and public facilities or a telephone booth are good examples. Altman sees a turn in line also as a public and very temporary territory.

An important difference between those three territories is duration. As mentioned in the definition of territory space, some territories (mostly public and secondary) can be temporary. This knowledge can become important when a robot needs to recognize territories. Another important difference is that of admittance or access of a territory. Temporary access may be granted to non-owners depending on the type of territory and its duration; janitors may access offices after working hours, and a policeman has access to a private home under certain conditions.

2.3.2. Markers

Markers are the means for laying claim to and preserving a territory. A marker is some kind of sign or signal that can help define or preserve a territory. Many different forms of markers exist, and they carry different purposes. According to Altman, they can either consist of actual physical boundaries or involve symbolic barriers (Altman, 1975, p. 123). Physical boundaries are, for instance, fences, doors, or walls that mark the size and existence of a territory. Goffman calls these boundary markers (Goffman, 1971, p. 42). In contrast to those, symbolic or central markers are "objects that announce a territorial claim, the territory radiating outward from it, as when sunglasses and lotion claim a beach chair, or a purse a seat in an airliner, or a drink on the bar the stool in front of it" (Goffman, 1971, p. 42).

Another symbolic approach to marking one's territory or the possession of an object is to claim or possess a territory next to the intended one (Goffman, 1971, p. 42). For example, a book or a personal object left on a newspaper lets people know, that the newspaper itself should also not be taken. "Hence, an object that is part of a territory can also function as a marker of a territory." (Goffman, 1971, p. 42).

Even people and their verbal and nonverbal signals can be seen as symbolic markers. For example, throwing a hostile look towards a potential intruder or warning someone away that might claim an already occupied library table can help mark or defend a territory, depending on the situation (Goffman, 1971; Sommer and Becker, 1969).

Finally, different strategies exist to use markers for claiming a territory. Goffman gives a very practical example: "Hence, on buses, streetcars, and trains, seats designed to hold two persons, and fully recognized to be designed to accommodate two strangers when necessary, nonetheless establish for the first arrival a territory he [the claimant] may attempt to retain for himself by standard ruses: he may leave his own possessions on the empty place, thereby marking it for his own and obliging competitors to move (or ask to have moved) something that symbolizes another; he may deny his eyes to those seeking a seat..." (Goffman, 1971, p. 34).

The knowledge about markers and their meanings can be helpful for a robot to recognize and respect territories, such as not opening a closed bathroom door. When a marker is misunderstood or ignored, it may lead to unintentional or intentional territorial intrusion.

2.3.3. Types of Territory Intrusion:

Territory intrusion takes place, when other people disregard the social territory of an owner and enter the territory without admittance. In the literature, many different terms for slightly different concepts exist for the process of intrusion.

Altman and Goffman, for instance, both use the term *encroachment* to describe the overall concept of invasion. Altman further distinguishes three different types. Violation, contamination, and invasion. Invasion describes the general process of trespassing without the owner's agreement, whereas violation and contamination do not necessarily imply entering. Contamination, for example, can include spitting onto somebody's lawn, violation could occur when a robot films and records personal documents in an office without permission.

Goffman separates encroachment into the concepts of *intrusion* and *obtrusion*. Intrusion has a similar meaning to Altman's invasion and can be motivated by several reasons. It can be unintentional if the territory is not perceived. It can be a "knowing by-product of some urgent design", for example in case of an emergency. And finally, it can be intentional with the purpose to offend (Goffman, 1971, p. 50). Obtrusion on the other hand happens, when the owner of a territory widens the boundaries and implicitly makes other people unintentionally intrude upon his territory.

Brown (2009), finally, defines a term slightly different from the concept of intrusion that he calls territory *infringement*. Interestingly enough, he describes this not as the actual act of intrusion, but as the *perception* of a person that someone, without permission "...has attempted to claim, take, or use a physical or social entity that the person believes belongs them" (Brown, 2009, p. 46). This definition stresses the position of the territory owner.

From now on, I will use the term infringement when referring to perceived territory intrusion by the owner, and the term intrusion to describe the process itself.

Naturally, infringement can lead to emotional and physical reactions from the owner, because it violates his, her or society's social norms. This is important to emphasize. All social spaces hold the potential to provoke emotional and possibly even physiological reactions from their owners: "Reacting to an infringement of one's territory serves primarily to restore the claim to the object. However, reacting can also function to provide an emotional expression of one's feelings towards the infringement" (Brown, 2009, p. 46).

And more importantly: "Such infringement experiences are inherently emotionally negative. Infringements threaten proprietary claim over a given territory, signal disrespect to the claimant, and violate norms of resource ownership and sharing within organizational contexts." (Brown and Robinson, 2011, p. 5).

This is especially of interest for two reasons: First, the fact that people react emotionally or physiologically towards infringement offers a possible approach to measure territorial behavior or other social space behavior and thereby indirectly measure their perception of territory. Secondly, the knowledge that infringement can lead to negative emotions of the territory owner is a huge motivation to help people (and perhaps robots) avoid it. For those two reasons, a closer look at territorial behavior is necessary.

2.3.4. Territorial Behavior (or Territoriality)

Territorial behavior can be described as the social behavior of a territory owner with the intention to claim or maintain his/her territory. Or in other words territorial behavior is "a self/other boundary-regulation mechanism that involves personalization or marking of a place or object and communication that is 'owned' by a person or group. Personalization and ownership are designed to regulate social interaction and to help satisfy various social and physical motives. Defense responses may sometimes occur when territorial boundaries are violated" (Altman, 1975, p. 107)

Again, different types of behavior can be distinguished. For example, Altman separates *preventive* from *defensive* territorial behavior, as a social practice that either helps define territories (e.g. by setting markers) and prevent infringement, or occurs after the infringement, such as vocal threats, threatening movements or aggressive gestures.

Brown is even more distinctive when suggesting four types of territorial behavior:

Control-oriented marking serves to clarify and accentuate boundaries of territories that should not be intruded upon. It has the purpose of showing that an object or place has been claimed by setting up markers.

Identity-oriented marking is a similar behavior that helps to express oneself and distinguish from others (e.g., setting up a Photo of ones family). This can be understood as some form of personalization.

Anticipatory defending is used to prevent infringement of ones territory. Especially when a person has reason to fear infringement, this behavior may take place. It serves to ensure continued ownership over a territory. Brown mentions a locked door or a password-secured computer as examples of this behavior. This resembles Altman's definition of preventive territorial behavior

Reactionary defending takes place after infringement. It serves to restore the claim to a territory and resembles Altman's definition of defensive territorial behavior. It can also serve as an emotional reactive outlet towards an infringement.

The knowledge about different types of territorial behavior could enable a robot to a social situation and adapt its conduct and planning accordingly. For example, if a person shows anticipatory defending, the robot could take extra care to avoid intrusion into his/her territory.

Depending on the type of territory (primary, secondary, public), reactions to infringement may differ. Intrusion into ones primary territory (e.g., home) certainly will trigger reactionary defending, but infringement on a public territory might lead to the abandonment of ones territory, if the cost is not too high (e.g., giving up a seat on a bus when other seats are available).

Although mentioned before, it is worth repeating that territorial behavior might be the best approach to study territory space. If some form of the above-mentioned behaviors can be observed, this leads to the conclusion that at least the person that shows territorial behavior perceives a territory space and potential or actual danger of infringement.

In the last section of this chapter, I will list similarities and differences of territory and personal space in order to motivate my focus on personal space literature for the study of territory space in HRI.

2.4. Similarities and Differences of Personal Space and Territory Space

Personal space and territory space have many similarities. Nonetheless, both spaces have features that clearly distinguish one from the other. Both social spaces can be used to describe and explain social (and often spatial) behavior between persons; however, as Sommer says: "The most important difference is that personal space is carried around while territory is relatively stationary." (Sommer, 1959, p. 284).

Also, while both spaces are human concepts with human owners, a territory space can belong to more than one person at a time and different persons over time. A personal space, on the other hand, is always connected to only one person.

Furthermore, the forms and manifestation of the respective social spaces vary immensely. Most often, territory spaces have visible symbolic or physical boundaries, in contrast to personal space, "...the latter having ever-shifting dimensions." (Goffman, 1971, p. 34). Or, as Altman puts it: "Territories, [contrary to personal space], necessarily include areas, objects, and places in the environment that exist only in real locations" (Altman, 1975, p. 128).

Finally, both spaces can be intruded upon and in both cases this can lead to psychological and social reactions (see Chapter 3 for study results of reactions to personal space intrusion). However, territory intrusion can take place during the absence of the owner. This leads, often, to a *delayed reactive* behavior. Also, the possibility of infringement can create *preventive* behavior. Reaction to personal space intrusion, on the other hand, is almost always instantaneous. Goffman agrees with this, when he notes "... a [territory] can be left temporarily while the leave-taker is sustained in a continuing claim upon it; personal space cannot." (Goffman, 1971, p. 33).

As was demonstrated by the examples in this chapter, territory spaces are important manifestations of social rules that can be found everywhere in our daily life. They can be observed through territory behavior and different forms of markers.

The similarities between personal and territory space listed above allow us to look into scientific studies with personal space and robots, as guidance for a study design dealing with territory space and robots. However, this should be done with caution, because of the many distinctions between the two spaces.

As will be seen in the next chapter, many studies exist in which the concept of a social space is either evaluated in HRI or implemented into the robot's behavior to improve the interaction with humans.

3. Related Literature on Social Spaces in HRI

As opposed to personal space, territory space has not yet gained much attention in human-robot interaction literature. Therefore, it is necessary to look into the wider field of all social spaces connected to HRI. Looking at the related work, one can separate the literature roughly into two slightly overlapping sub-categories. One category has the *usage* of a social space at it's core. Often, the navigation or approach of a robot is improved, but papers exist where other aspects of the robot's behavior (e.g., starting a conversation) are referred to, as well. The second category contains papers that focus on *fundamental research* of a social space in HRI.

3.1. Approaches from HRI that use Social Spaces

The study by Yoda and Shiota (1997) is probably one of the first papers from HRI that models a robot's behavior by respecting a social spaces. In this study, a mobile robot was implemented with a human-passing algorithm that respects the personal space of the human.

Another early paper that uses the concept of personal space for modeling socially acceptable robot behavior is that of Nakauchi and Simmons (Nakauchi and Simmons, 2002) - "A social robot that stands in line". The authors present a robot, that can queue up in a cafeteria line by respecting the personal spaces of other persons in the queue. It is only one of many papers that use social spaces for the modification of the robots social behavior (e.g., Kirby et al. (2009), Torta et al. (2012)).

In other studies, the concept of social spaces is used to give the robot information about humans and their social relationships. For example, in "A spatial model of engagement for a social robot" (Michalowski et al., 2006) the robot deduced their suitability for engagement into a conversation by categorizing people according to their position in the four different zones of the robot's personal space.

One of the first studies that used *activity space* for an improved social interaction was published by Althaus et al. (2004). They looked at different ways for a robot to join a group of people involved in conversation.

In another paper, moving patterns of subjects in a shopping mall were observed and basic patterns deduced. These moving patterns are not unlike activity spaces and help the robot decide what activities the people are currently executing. Based on this knowledge, the robot decided whether to approach a human or not (Kanda et al., 2009).

For a robot's real-time analysis of the social situation, Mead, Atrash and Mataric looked at different personal space metrics from the social sciences and tried to find out whether it is possible to evaluate human proxemic behavior automatically (Mead et al., 2011).

One of the few HRI papers that contains a concept similar to territory space is that of Sehestedt (Sehestedt et al., 2010). To improve the social behavior of a mobile robot at the workplace, the trajectories of humans are observed and learned by the robot. The authors use a hidden Markov model approach to learn different movement patterns. Building on this information, path planning is done with an A*-algorithm. The goal for the robot is to "avoid planning paths through someones personal space where he is sitting" (Sehestedt et al., 2010, p. 2038) or, in other words, to avoid *intrusion* into the work-space of the person, while they are present.

To summarize, the successful improvement of a robot's social behavior via the application of social space concepts has become important over the last decades. They give reason to consider the study and implementation of the territory space, as well. Finally, they offer approaches and methods that could be adapted for the implementation of territory space behavior. For example, instead of observing moving patterns to determine activity spaces, observation of marking and other territorial behavior could be implemented to determine size and ownership of a territory.

3.2. Approaches from HRI that measure Social Space Parameters

Pacchierotti et al. (2005) were some of the first researchers to investigate, rather than use, personal space in HRI. They evaluated the acceptability of a robot's passing-behavior in a hallway setting, looking at influencing factors such as speed and signaling distance.

Similarly, Walters et al. (2006) looked at the approach distances and directions between Robot and Human. Participants were told to approach a robot and stop at a distance, that they still felt comfortable at. Afterwards, the robot approached the subject, until being stopped verbally by the subject. In other words, intrusion was used to determine the spatial relationship between robot and subject.

Instead of measuring distance, another approach is to observe spatial patterns via video recording. In the same year as Walters et al., Hüttenrauch and Eklundh looked at subject's spatial behavior while interacting with a tele-operated robot in a living home environment. They found that subjects do indeed concede to spatial patterns which resemble social spaces, namely the personal space and the activity space (i.e., F-Formations) (Hüttenrauch et al., 2006). Based on these results, Kuzuoka et al analyzed how the robot's body torque can influence F-formations between humans and robots (Kuzuoka et al., 2010).

Syrdal (Syrdal et al., 2008) studied the influence that the appearance of a robot can have on the subject's expectation of the robot's proxemic behavior. They found that the more anthropomorphic a robot looks, the higher the expectation of subjects is that the robot will show adherence to social rules and norms (e.g., respecting someone's personal space). Takayama and Pantofaru examined other factors that could influence a persons proxemic behavior in HRI, such as 'experience with robots' or 'head orientation of the robot' (Takayama and Pantofaru, 2009) . This shows that a study of social space with robots should consider influencing factors, such as the appearance of a robot. Other interesting factors could be the ownership of the robot, or the activity it is executing.

Approaches like these emphasize the need to not only look at the existence of social spaces in HRI, but also consider external influences that might change the place social spaces take in HRI contrary to HHI. Not only is it important to consider similarities between human-human and human-robot social interaction - knowing about the differences is crucial as well.

To that effect, Joosse et al. (2011) provoked personal space invasion in order to find out whether intrusion by robots is perceived differently than intrusion by humans, and also what effect approach speed has on this perception. Here, the attitudinal and behavioral measurement BEHAVE developed by Joosse was used to determine subjects physical and attitudinal reactions.

Other than using attitudinal (questionnaires) or behavioral (observation of subjects behavior) responses of subjects to measure reaction towards the robot's behavior, it is also possible to measure *physiological* reaction, as the following study demonstrates. Among other instruments, the galvanic skin response-level (i.e., the skin conductance) of subjects was measured to interpret reactions towards a robot and it's proxemic behavior under differing conditions (such as verbal- vs. non-verbal cues and approach initiative) (Okita et al., 2012). Again, indirectly, intrusion into the personal space was used to assess if the person would react with an elevated skin conductance level or not. It was found that verbal and non-verbal prompting decreases the distance between subjects (adults as well as children) and robot.

To summarize, the fundamental research on proxemic behavior in HRI uses different attitudinal, behavioral, and physiological methods to determine subjects reactions. Almost always, the intrusion into a social space is used to provoke a reaction. Based on these results, the study design of this thesis can be developed. Using intrusion to provoke a reaction from participants will be used to develop a study design that concerns itself with territory space in HRI contrary to the many papers examining personal or activity space. This will be presented in the following chapter.

4. Study Design: Thought Simulation and the Workplace

In this chapter, I present and motivate the instruments used in the study, as well as all the different aspects of a study such as the scenario, the approach and the independent variables. Since one of the instruments is skin conductance, a short digression into this topic is included in this chapter as well. Finally, the procedure is described.

4.1. Approach

From the definition of territory space in Chapter 2 it follows that the existence of territory space can best be observed when humans show territorial behavior. Placing or respecting markers, defending or defiling a territory - territorial behavior constitutes, forms and justifies territory space. It seems reasonable, then, to conclude that by observing territorial behavior in my subjects I can observe the existence of territory space.

As was demonstrated in the previous chapter, many approaches exist in the literature for measuring social spaces (personal space and activity space) in HRI, using instruments such as questionnaires and behavioral observations. It was stressed that very often these approaches include some form of intrusion into the social space in order to provoke a reaction (e.g., Pacchierotti et al. (2005); Walters et al. (2006)). So, to provoke infringement in my participants means to provoke a reaction from them, which can be measured and evaluated.

Involving a live experience of intrusion into a subjects territory space is not practical. Contrary to personal space, humans don't carry territory space with them. Therefore it would be necessary to visit subjects in their territory spaces to be able to provoke robotic intrusion. Additionally, it could prove very difficult to find subjects who are already used to robots working in their environment. This step would be necessary to eliminate the possibility that subjects reacted only towards the unexpected appearance of the robot and not to it's territory intrusion.

Therefore, I made subjects think about territory intrusion. In other words, a thought experiment of territory intrusion will be used to provoke reactions. The idea is to play participants an audio recording that describes a typical day of them in the future, involving robotic intrusions. Subjects will be asked to imagine the scenarios happening in the audio text and possible reactions will be measured.

It was found that people prefer more humanoid appearance robots to stay farther away than more mechanoid looking robots (Dautenhahn, 2007). This suggests that the appearance of a robot influences the spatial relationship between the robot and the subjects. In order to keep this influence constant and to help people imagine the scenarios, two pictures (see 4.1 for one example) of the robot PR2[1] will be presented to avoid different subjects imagining different kinds of robots (e.g very mechanoid or very anthropomorphic).

Environment In their study on territory infringement, Brown and Robinson (2011) found that territoriality does exist at the workplace, and that factors, such as type of infringement

[1] PR2 is a robot developed by WillowGarage: `http://www.willowgarage.com/`

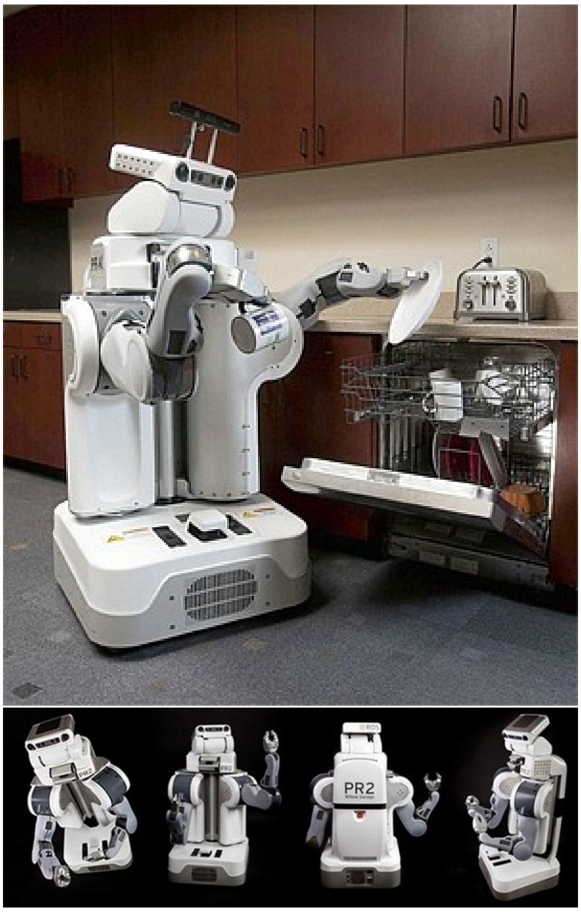


Figure 4.1.: The two pictures presented to the participants to help them imagine the robot during the audio recording. Both show the robot PR2. The first is from: `http://apps.startribune.com/blogs/user_images/marthabuns_1320858949_1robots1110.jpg`, the second from `http://www.hsi.gatech.edu/hrl/project_pr2/pr2montage.jpg`

and strength of the psychological ownership, influence the amount of territoriality. These results together with Sehestedt et al. (2010), see Chapter 3, suggest the importance of the territory space at the workplace. Furthermore, the workplace is a secondary type of territory. Those territory spaces exist for a rather long period of time and contrary to public territories, subjects will still make a rather strong claim on their territory. Also, there can be a rather high fluctuation of different social groups and individuals at the workplace, which heightens the demands on a social robot and strengthens the importance of its socially acceptable behavior. Finally, this environment offers territories that a robot is able to interact with and intrude on. Other territories that have been studied in the literature are rather difficult for a robot to interact with, such as picknick table in a park, or a beach chair. These are arguments for the workplace as the environment of my study, and the personal office as the secondary territory. In Figure 4.2, a typical situation of a robotic intrusion into an office is depicted.

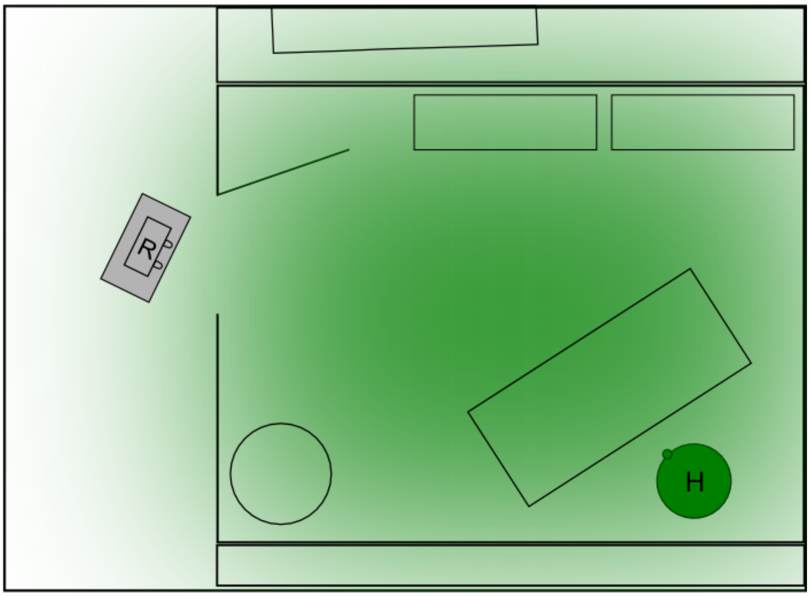


Figure 4.2.: This figure depicts a typical situation of robotic intrusion at the workplace. It shows a person sitting in his personal office, with the green sphere representing the territory space and the robot about to enter the office and possibly intrude on the territory.

Influencing variables (predictors) Territory space, contrary to personal space, can be intruded upon while the owner is absent, therefore presence of the owner is an interesting possible predictor. Especially with future employment of robots at the workplace in mind, it would be interesting to know whether a territory owner shows a different reaction - for example to feel less infringement - towards intrusion when he is absent (i.e., finding out that a robot was in his/her office). If so, the robot could decide to enter a territory while the owner is absent, so as not to make him/her feel uncomfortable. Therefore, this predictor shall also be included in my study.

Also, it is conceivable that the activity which the robot is executing (e.g. bringing something into the territory, taking something away) could influence the perception of infringement. Different social roles have different rights of access to a territory. A janitor or building owner can expect access to an office, at least at certain time of day. A colleague, on the other hand, could be expected to wait for a sign to enter (e.g., a verbal invitation to come in). The reason *why* somebody enters a territory might influence his/her right to enter it, without intruding upon it. Therefore, my second predictor is 'type of activity' (from now on 'activity').

I selected the following six activities, based upon typical tasks a robot might execute that involve entering an office:

- Robot enters office to ask a question
- Robot enters office to turn off the light (to save energy)
- Robot enters office to vacuum the floor
- Robot enters office to connect himself to electrical outlet (to charge its battery)
- Robot enters the office to deliver a package
- Robot enters office to borrow a ruler, bringing it to someone else

Scenario As was mentioned above, the thought experiment was conducted through an audio recording. An introductory audiotext as well as two versions of a main audiotext were developed. All texts are written in second person, to help subjects put themselves into the position of the person in the text (See Appendix A,B for the texts (German version)).

The *introductory text* prepares subject for the main audio by describing the background settings and asking subjects to imagine their own office in the company, for example: "Think about what your office would look like. Do you have pictures of your family or posters of your favorite band on the walls?". This held the purpose to help subjects identify with their office and to strengthen their territorial claim on it.

Each version of the *main audio text* describe a typical workday of the subject. The description starts with the arrival at work, describes several tasks and actions of the person over the day and contains 9 different scenarios, where a robot is involved. In six of those scenarios, the robot enters the office without permission and executes one of the six above-mentioned activities. The two versions of the text differ insofar as the subject is either present or absent during the intrusion.

4.2. Instruments

Three different instruments were selected for my study. Since, according to Brown, even in human-human interaction, empirical studies on *measuring* territoriality are rare (Brown, 2009, p. 45) two of those instruments were adapted from other fields and one instrument was developed on my own. I decided to use and adapt a questionnaire from HHI intended to evaluate subjects comfortableness with a humans intrusion into territory space. And I chose to adopt a physiological method that was used to measure reaction to personal space intrusion.

4.2.1. General Questionnaire (GQ)

In their paper on territory intrusion at the workplace, Wollman et al. (1994) asked workers about potential work space invasion, using, among others, a 7-item questionnaire. This approach is very fitting to my study for several reasons. The environment of their territory is the workplace. Also, the questionnaire asks about *potential* territorial intrusion. Since as of today not many institutions employ robots, my subjects will most likely have no experience with robotic intrusion. Therefore, a hypothetical approach is the most reasonable one. Finally, the study examines territory *intrusion*, and not other territorial aspects.

Because the questionnaire was developed for human psychology studies I had to adapt it to fit field of human-robot interaction. My adapted German version of the questionnaire can be found in Appendix F. All questions are phrased as: 'How much would you mind if a robot...' and can be answered with one of 7 points on a Likert[2]-scale with a range from 'Not at all' to 'Very Much' (see figure 4.3 for example).

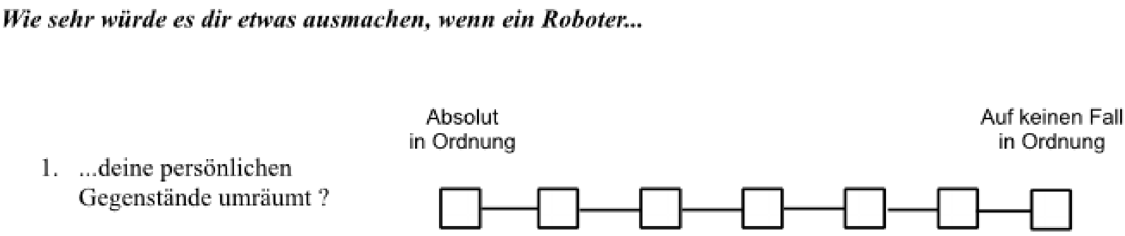


Figure 4.3.: One sample question from the General Questionnaire. The question is: 'How much would you mind a robot... ...moving your personal items' and answers range from 'not at all' to 'very much'

4.2.2. Main Questionnaire (MQ)

I developed a questionnaire for the audio-texts, fitting it to the two distinct predictors that were involved (see figure 4.4 for an example and the appendix for complete versions). Since two versions of the audio-text exist with respect to the predictor presence, two versions of this questionnaire were developed.

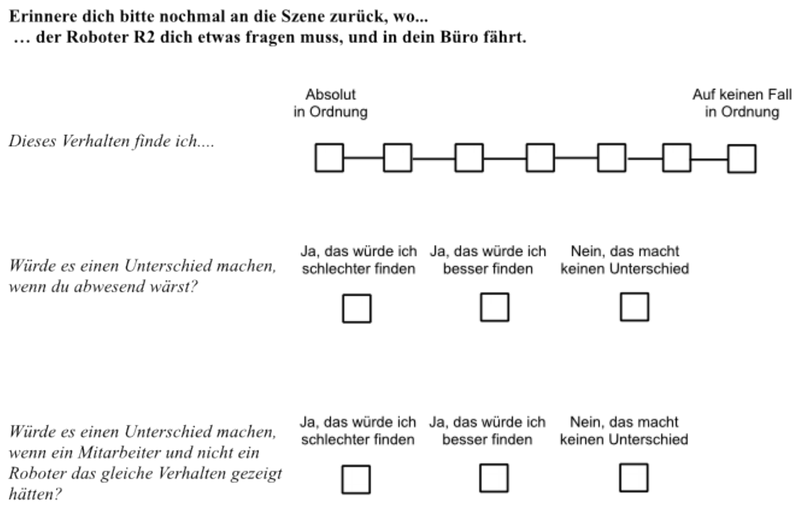
Each questionnaire consists of six different blocks, respectively referring to one of the six different activities where territory intrusion takes place. Each block contains four different items:

1. The first question is a 7-point Likert question as in the GQ. It is always phrased 'How much did you mind the robot's behavior when he ...' followed by a description of the respective action (e.g., '...entered your office and delivered a package'). As in the General Questionnaire, answers were to be given on a 7-point scale with values between 'not at all' and 'very much'.

2. The second item was phrased, 'Would it have made a difference if a human and not a robot had shown this behavior'. Here, only a 3-point scale was offered, with the possible answers 'no difference', 'yes better', and 'yes worse'. This question served to check whether subjects perceive differences between a human and a robot executing the respective behavior.

3. The third item asked, 'Would it have made a difference if you would have been present/absent' and had the same answer-range as the previous question. This item served to examine the predictor Presence.

[2] Likert-Scales are typical instruments in questionnaires and usually several items exist to research one question. It is common to calculate the mean over each group of items that refers to the same question.


Erinnere dich bitte nochmal an die Szene zurück, wo...
… der Roboter R2 dich etwas fragen muss, und in dein Büro fährt.

Absolut in Ordnung — Auf keinen Fall in Ordnung

Dieses Verhalten finde ich....

Würde es einen Unterschied machen, wenn du abwesend wärst?
Ja, das würde ich schlechter finden — Ja, das würde ich besser finden — Nein, das macht keinen Unterschied

Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?
Ja, das würde ich schlechter finden — Ja, das würde ich besser finden — Nein, das macht keinen Unterschied

Figure 4.4.: One sample block from the main questionnaire with the three relevant items. The leading questions is: 'Please remember the scene... ... where the robot R2 needs to ask you something and enters your office'

4. The last question was a free-text question and asked 'Can you remember what you did when the robot showed this behavior?'. It served as a distractor item and was not intended for evaluation. It was supposed to help avoid subjects thinking too much about what the questionnaire was examining.

4.2.3. Electrodermal Activity

Since this study is one of the first to research territory intrusion in HRI, I felt it necessary to use different kinds of measures in order to enhance the informative value of the study. Therefore, a third -physiological-instrument was selected. Simultaneously, this served the purpose to reduce the problem of social desirability[3], since physiological reactions are much more difficult if not impossible to manipulate by participants.

Kulic and Croft (2005) compared different measures for anxiety detection in HRI, among them skin conductance. Although anxiety detection is not part of my study, this demonstrates that it is indeed possible to measure participant's response to robot's live behavior with skin conductance or electrodermal activity (EDA).

In their paper 'Social proximity effects on galvanic skin responses in adult humans' McBride et al. (1965) used skin conductance and 'distance between experimenter and subject' as measurements for the reaction towards personal space intrusion by the experimenter. They found that subjects do indeed react with heightened skin conductance and that reactions were strongest when approached directly from the front by a male experimenter. This proves that skin conductance is a possible instrument for measuring personal space intrusion in HHI.

In a similar study design, EDA-measures were used to examine social distances between robots and humans (adults and children). Okita et al looked at different factors such as 'initiation of approach' or 'verbal vs non-verbal gestures' Okita et al. (2012). The results

[3] Social desirability is the tendency of subjects to answer questionnaires or behave in experiments in a manner that can be expected to be seen favorably by other people. Therefor it is often helpful not to let participants know what is being examined in the study

showed that verbal and non-verbal prompting indeed influences the physical distance participants still feel comfortable at. More importantly, however, the study demonstrated that skin conductance can be used to examine spatial relationships between humans and robots.

Taking all three studies above into account, it seems feasible to use skin conductance as an instrument in HRI at least for personal space intrusion. As was argued before, since personal space and territory space have many similarities, it is possible that measures for personal space intrusion could work with territory intrusion as well. Therefore, I will use skin conductance responses in my study as a third instrument and a short digression into the field of EDA is necessary:

4.2.4. Digression - Electrodermal Activity

Electrodermal Activity, formerly known as galvanic skin conductance, is the electric activity of the skin. It is thought to be strongly related with the central nervous system and therefore serves as a good indicator for psychological reactions to an emotional or affective stimulus. (Boucsein, 2012, p. 24, p. 41, p. 84). This is explained in part by the eccrine sweat glands of the skin that are mainly found in the palms of the hands and at the soles of the feet. They are thought to react strongly to psychological events through so-called emotional sweating (see Stern et al. (2001)) and thus influence the EDA[4].

Application fields of EDA-measurement

Besides application fields such as biofeedback or habituation, EDA has been used as an indicator for many different psycho-physiological states. For example, to measure emotion, stress and many more[5]. Another of those states is that of arousal: "...tonic EDA parameters have been, for a long time the most frequently used indicator of arousal in psycho-physiological research"(Boucsein, 2012, p. 348). It is this state, that is most often and easiest measured, when looking at subjects reaction's to a stimulus.

Measuring EDA

There exist two different methods on measuring EDA (Stern et al., 2001, p. 207). The *endosomatic method* merely measures the electric activity on the surface of the skin. The *exosomatic method* sends a small current through the skin and then measures the resistance as 'skin resistance'. The latter method is used today for measuring the reciprocal of skin resistance, the so-called skin conductance (SC). It is the method of choice for most researchers (Stern et al., 2001; Boucsein, 2012) and will be implied from now on when talking about measuring EDA. Today, SC is measured in micro-Siemens[6] by applying a constant voltage (somewhere around 0.5 Volt (Boucsein (2012))) or alternatively a constant current. Again, the former approach is the method of choice in this study.

Skin conductance is recorded by connecting electrodes to the surface of the skin. Sometimes, a conductive paste is used to enhance conductance. The electrodes can be connected at different places of the hand (or feet). Bipolar placement (see Figure 4.5) for example

[4] For a further explanation of the relationship between the central nervous system and EDA see Boucsein (2012) and Stern et al. (2001)

[5] Other fields of application are engineering psychology (e.g., different kinds of strain at the workplace) or human-computer interaction. "A continuous online recording of EDA may also play a key role in the interaction of users with virtual agents...., if the interaction between avatar and user is aimed at an interaction between humans, psycho-physiological responses may have to be added to this very special kind of [human-computer interaction]"(Boucsein, 2012, p.467).

[6] Micro-Siemens is defined as the reciprocal of Resistance (ohm) and therefore has the abbreviation (mho)

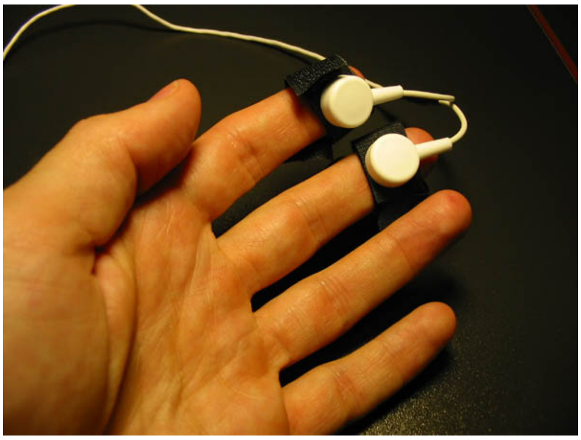


Figure 4.5.: Sample Picture of bipolar electrode placement. This picture comes with the documentation of the measuring software that was used in this thesis: BioTrace+ (`www.mindemedia.nl`)

would position the electrodes at two different points of one hand, such as the medial phalanx or the distal phalanx of the index and middle finger of the non-dominant hand (Boucsein, 2012, p. 106).

Looking at SC-data, one can distinguish an ongoing tonic activity called skin conductance level (SCL) and a phasic activity called skin conductance response (SCR) Stern et al. (2001); Boucsein (2012). Both levels are necessary for the deduction of information from SC-data, therefore they are shortly described below.

Skin Conductance Level The SCL or tonic activity is the slow-changing trend of skin conductance. It can best be observed in the absence of any SCRs. Therefore, all SCRs are usually calculated first and subtracted from the raw data. Then, the SCL becomes visible. It is common to calculate the average base level of SCL using only the SCR-free SC-data at points just before the beginning of SCRs (Boucsein, 2012, p. 173).

Skin Conductance Response SCR can be observed as a reaction to sudden external stimuli, and is therefore most often the measure of choice in a stimulus-experiment (see Figure 4.6 for a typical SCR).

A SCR is always monophasic (Boucsein (2012)). One SCR has several parameters that are important for further evaluation. One of those parameters is *latency*. It is the time from the stimulus onset to the onset of the SCR and lies somewhere between 1-3 (Stern et al., 2001, p. 208) or 1-5 seconds Boucsein (2012).

Another parameter of SCR is the *amplitude*. It is necessary to define a minimum amplitude to determine whether a peak in the SC-data counts actually as a SCR or just as noise. It is common to set a minimum amplitude around 0.5 micro-Siemens (Boucsein, 2012, p. 156). Every peak below does not count as a SCR but rather as part of the tonic SCL.

It is possible that several consecutive SCRs can superimpose each other and the undergoing SCL. In Figure 4.7 one can see two different SCRs superimposing each other, which in the SC-data looks like the green curve in the top of the figure. It is a great challenge to separate the individual SCRs and decompose the SC-data into its phasic and tonic components.

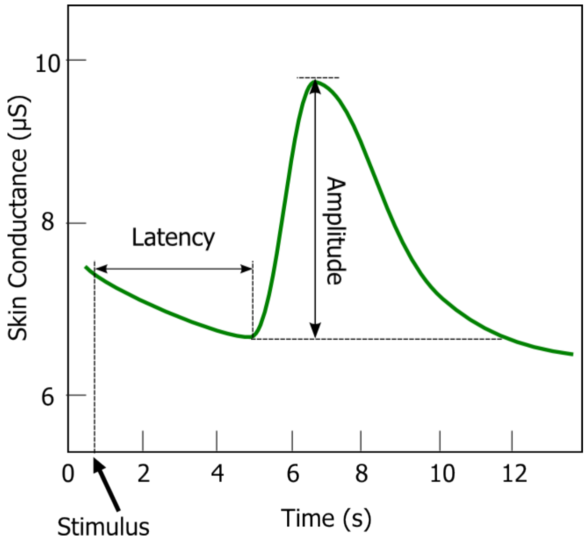


Figure 4.6.: This is a typical SCR shape that can occur after a stimulus

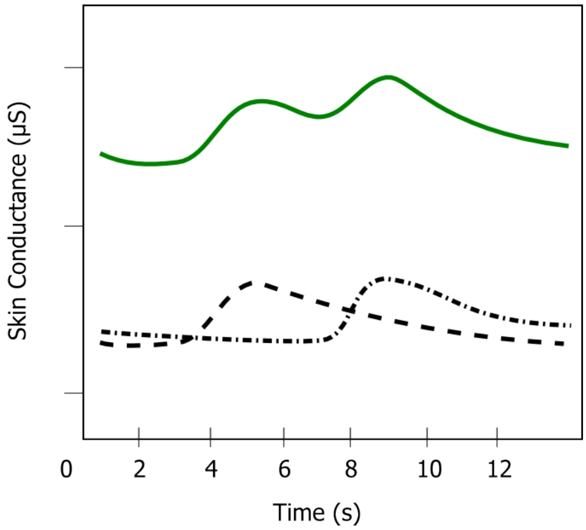


Figure 4.7.: Two overlapping SCRs produce one combined shape

Artifacts As was mentioned above, noise also known as spontaneous or non-specific skin conductance activity is one artifact that is very common in EDA. It should not be confounded with the SCRs as a reaction towards a stimulus (Boucsein (2012)). Also, body movement and respiration were found to influence SC-data and produce similar artifacts as the usual noise does. Therefore, artifacts need to be filtered out before further analysis takes place. Boucsein suggests low-pass filtering as "..an easy to apply method of artifact removal from eda recordings, since the [SCR] constitutes a rather slow-changing signal...;" (Boucsein, 2012, p. 189). Further external and internal influences that should be controlled or at least observed during recording are for example room temperature, skin temperature and blood flow, age, and gender.

Analytic Procedures

The standard method for identifying SCRs is a peak-detection method (Benedek and Kaernbach, 2010, p. 648) called "Peak-To-Trough". In this approach, the difference between each succeeding peak and trough (SC maxima and minima) is computed, and those peaks that exceed the minimum amplitude are counted as SCRs. This approach is very simple and therefore entails some disadvantages. If several SCRs follow each other quickly, superposition takes place; that is, recovering SCRs distort succeeding ones (as was shown in figure 4.7). This makes it difficult to distinguish distinct responses (Benedek and Kaernbach, 2010, p. 648). Recently, more advanced and complex procedures were developed to analyze raw SC-data, and (Boucsein, 2012) recommends the following approach in the second edition of his book 'Electrodermal Activity':

Decomposition of skin conductance data by means of non-negative deconvolution (DDA)

This approach assumes a model of the electrodermal system where each SCR consists of two underlying physiological processes. (Edelberg (1993): an unconditional diffusion process, and a pore-opening process (Boucsein, 2012, p. 171). If this model is implemented, it allows for the identification of many more different SCR-shapes in SC-data).

It is assumed that the SCR is a driver function which has either a zero baseline or positive impulses that are compact in time (with a marked onset and offset; (Benedek and Kaernbach, 2010, p. 650)). Contrary to standard deconvolution methods, in this method, no negative values are allowed. This is due to an adapted mathematical function (dividing digit by digit instead of cutting the division short at the first digit). The method yields a better driver function, which can distinguish more SCRs from non-specific amplitudes.

The approach consists of 4 steps:

1. Estimation of the tonic component

   In this step, a Bateman function[7] is used to identify all SCRs, possibly including negative values. It serves to find all SC-data free of phasic activity. Since data deconvolution can amplify error noise, the resulting function is smoothed with a Gaussian Window. Afterwards, peak-detection is performed and tonic activity is interpolated, resulting in a “quasi-steady function ”(Benedek and Kaernbach, 2010, p. 652). Then the tonic data function is subtracted from the raw SC-data. This leaves phasic SC-data representing all SCRs.

2. Non-negative deconvolution of the phasic component

   After first correcting the phasic SC-data, non-negative deconvolution is applied, resulting in a non-negative driver function and a non-negative remainder. After smoothing the data again, impulses (i.e., SCRs to events) become visible.

3. Segmentation of driver and remainder

   After making the SCRs visible, single impulses are identified, using peak-detection analysis.

4. Reconstruction of the SC-data

   In the last step, the data is reconstructed. Now, additional data such as amplitudes of the SCRs can be deduced.

Afterwards, optimization of all parameters involved in the process can take place and the whole procedure is repeated with the new parameters. The software Ledalab [8] has im-

[7]The Bateman function is a mathematical function developed by the English mathematician Harry Bateman. The function describes the invasion and elimination of a material and is a special form of a hyper-geometric function.

[8]Ledalab is a free software downloaded from: `http://www.ledalab.de/`

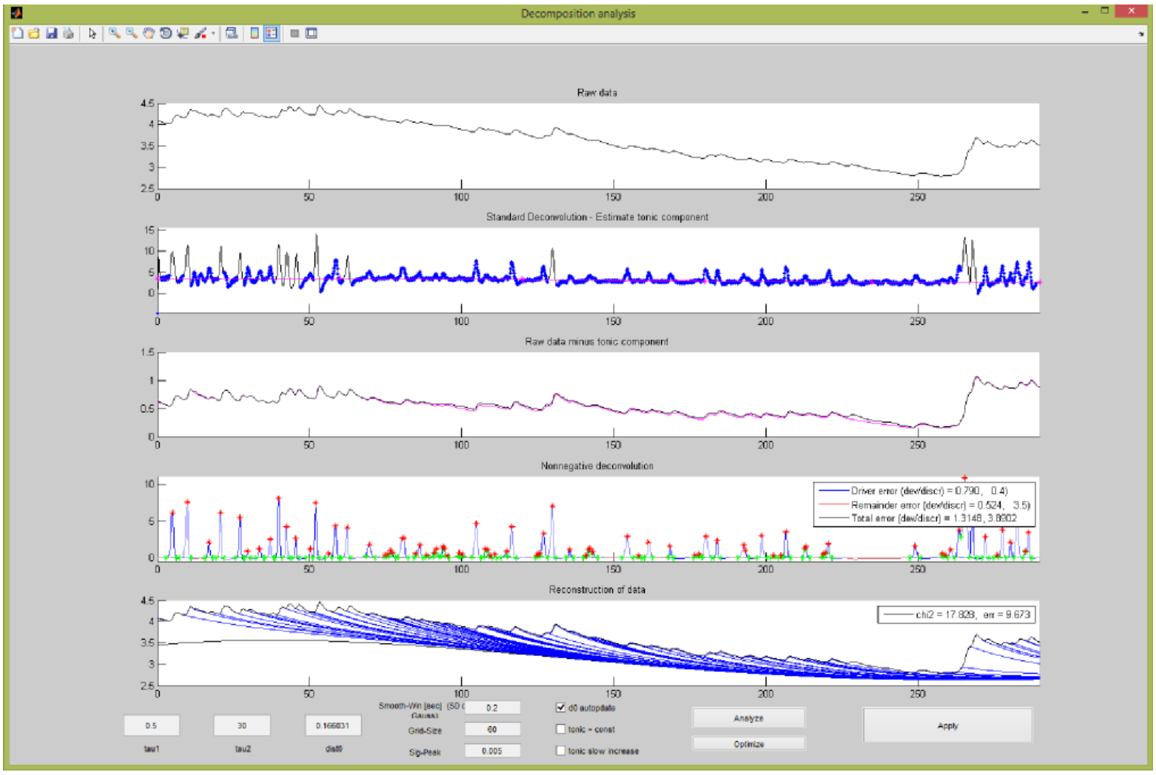


Figure 4.8.: The Software Ledalab showing the four steps of DDA that is implemented as an evaluation method

plemented this procedure and I will use this software for my preparation of the SC-data. (Figure 4.8 shows the software and the four steps of the DDA-method).

4.3. Procedure

After preparation of the instruments and audio-texts, the study was proceeded over the course of two weeks as follows:

The study took place in a neutral living-room environment. This way, subjects weren't confronted with unfamiliar and unsettling surroundings. Also, this environment was intended to support easy immersion into the described scenario. Anonymity of the subjects was stressed to avoid social desirability effects and they were asked to sign a declaration of consent. All subjects willing to participate were introduced to the EDA-measuring device.

Subjects were asked to wash their hands (with water and soap), as is recommended for bipolar electrode placement (Stern et al., 2001, p. 212).

The two pictures of the robot (introduced in section 4.1) were presented to the participants and they were told to imagine this kind of robot while listening to the audio recordings.

Since room-temperature was identified as an influence on SC, I tried to keep it constant at 20 °C. Then, the subjects were connected to the EDA-device using two electrodes on the non-writing hand of the subjects (distal phalanx of the index and middle finger). Following Benedek and Kaernbach, no isotonic electrode paste was used (Benedek and Kaernbach, 2010, p. 651). Subjects were asked to keep as still as possible during the session.

The raw data was sampled at 32Hz. Other studies have uses additional measures such as heartbeat and skin temperature in order to enhance informative value. I chose to omit other measures as it was beyond the means of this study and several papers limit their physiological measure to EDA (Benedek and Kaernbach, 2010, p. 84).

When the subjects were ready to start, the introductory audio-text was played, describing the office of the subject. This was to help the subjects emphasize with the situation and build up an image of their office-territory. Also, this period was used to check whether the EDA-device was working correctly. Finally, this period served to give subjects the chance to acclimate themselves, thereby allowing the electrodes to equilibrate with the skin.

Afterwards, the recording started and one of the two versions of the main audio text was played. Then, the questionnaire I developed was presented and subjects were told to read the questions carefully and ask for help if anything was unclear.

Finally, the general questionnaire was presented and subjects were specifically told that this questionnaire was unrelated to the audio-text. I deliberately chose to present this questionnaire at the end. It would have been possible to present it before the audio-texts, but the questionnaire is very obvious about its subject: territory intrusion. I did not want to prime the physiological data with the questionnaire by making participants aware of what the study was about before listening to the audio. Therefore, I chose to present it after the main experiment-accepting that comparison with other studies that used Wollman's questionnaire for the evaluation was not possible.

In the following chapter, the results of the study are presented and evaluated.

5. Evaluation

In this chapter, I will first describe how the raw data from my study was prepared for evaluation. Then I will present the results from the evaluation for each of my instruments individually, in the same order as they appeared in the procedure. Each evaluation will be separated into a part where descriptive statistics will be presented (i.e., what does the data look like) and then where the inferential statistics are described (i.e., how significant is it).

5.1. Preparation of the Data

Electrodermal Activity Before I could evaluate the collected data, I had to transform it for evaluation purposes. For the skin conductance data (SC-data), I manually set markers at all points in time where a robot started its intrusion into the office (i.e., for all six activities). Those, together with the SC-data itself were exported in txt-files and imported into Ledalab, the EDA-analysis software mentioned in Chapter 4.

For each file (i.e., for each subject) the following procedure was used individually: after import, the data was smoothed and artifacts such as wild movement, or outside noise that I recorded during the sessions were marked. Then the analyzing-method 'Decomposition of skin conductance data by means of non-negative deconvolution' was selected. As described in Chapter 4, this method consists of several steps, where SCL and SCRs are identified. Each data-set was optimized several times, until the calculated error was no longer decreasing.

Then, DDA was applied on the data, one final time, and the results were exported using the Export-Event function from Ledalab. This function exported all SCRs above a fixed amplitude within a set window of time after an event-marker. I set the minimum amplitude at 0.01 micro-Siemens and the window of time between 1 to 4 seconds after the event. This is given as an example on the Ledalab website and reported as one of several common thresholds by Boucsein (Boucsein, 2012, p. 157,p. 151).

Afterwards, each individual text-file was imported into R[1] and the data was transformed, resulting in a data-set consisting of data for 20 subjects with several different variables such as 'numbers of SCRs in the time window' or 'latency of the first SCR'.

Finally, information about the variable Presence[2] for each Activity was added, meaning that each participant received either a 0 or 1 in the variable Presence for each Activity. The variable containing the number of counted SCRs for each Activity was duplicated and transformed into a boolean variable, where 0 meant no SCRs and 1 stood for one ore more SCRs. This new variable will be called SCRbool. It is the main dependent variable for the EDA-analysis.

Main Questionnaire The questionnaire-answers were translated into numeric values. Since the last question ('Do you remember what you did while the robot showed this behavior?') served only as a distractor, those answers were ignored. Therefore, the data-set for the first questionnaire contains the following three dependent variables:

[1]R is a free software for statistical evaluation - see `www.r-project.org`

[2]For better understanding all involved dependent (EDA-data,questionnaire answers) and independent (Age, Gender, Presence, Activity) variables will be written with capitals, to distinguish them better.

1. Main Question (MainQ) - 'How much did you mind the robot's behavior, when he...?'- For the main question the range between 'not at all' and 'very much' was coded with numbers from 1 to 7. Since MainQ consisted of only one item, MainQ was treated as ordinal-scaled.

2. Human Question (HumanQ) - 'Would it have been different, if a human and not a robot behaved in that way?'- The answers to this question were coded with the numbers 1 (human would have been worse), 2 (no difference) and 3 (human would have been better). HumanQ was treated as a 3-point categorical variable.

3. Presence-Absence Question (PresAbsQ) - 'Would it have made a difference if you were present / absent?'- Answers to this question were transformed into a binary variable (with values 'presence makes a difference','presence makes no difference')

Just like for the SC-data, information about Presence was added respectively for each subject and Activity.

General Questionnaire Each item from the GQ was coded like the main question from the MQ, using values between 1 and 7. Then, as is standard procedure for Likert-Scale items referring to the same scale, the mean was calculated over the eight items for each person. This variable will be called Score.

For all three measures, additional information on gender and age was added for each subject. The independent variable Age was treated as a binary variable just like Gender, separating subjects into groups older and younger than 40 (with values 'under 40' and 'over 40').

5.2. Results

5.2.1. EDA

Altogether, 20 subjects participated in the study (10 female), between the ages of 23 and 64. As was the design of the study, for each scenario 10 participants were in the absent-condition and 10 participants in the present-condition. For the EDA-data, only 19 participants could be evaluated, due to recording error in one session.

Descriptive Statistics

First, a look at the descriptive measures of the data will be taken. The frequency histogram (see Figure 5.1) shows that for all Activities there were more participants that had no SCR than there were subjects that did have one.

This relation does not seem to depend on the variable Presence. When we look at both histograms in figure 5.2, where Presence is controlled as either present or absent, we can see, that again over all Activities more often no SCR was found.

This relation can also be found when distinguishing subjects by Age and by Gender (see figure 5.3). Whether significant differences exist will be evaluated in the following section.

Inferential Statistics

In order to determine which methods from inferential statistics may be used, I must first consider the variable in question and its distribution.

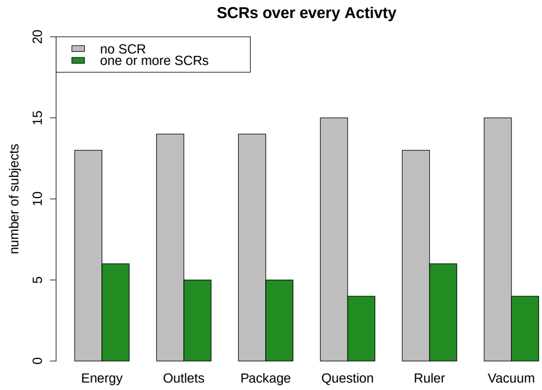
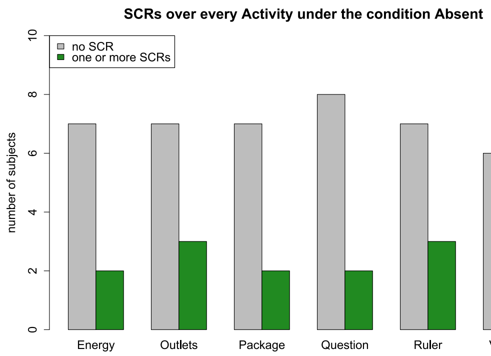
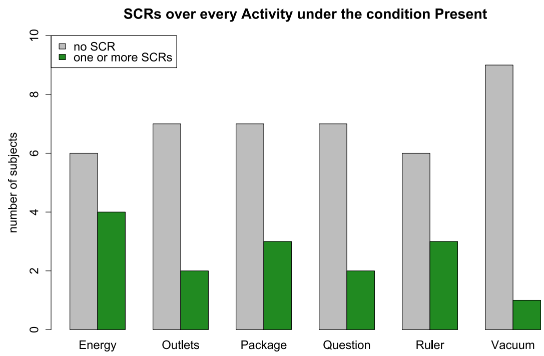


Figure 5.1.: Histogram on number of subjects for each Activity that did or did not have SCRs for the Activity



(a) Absent condition



(b) Present condition

Figure 5.2.: Both histograms show number of subjects that did or did not have SCRs for each Activity, looking only at subjects that were either absent (5.2a) or present (5.2b) during intrusion

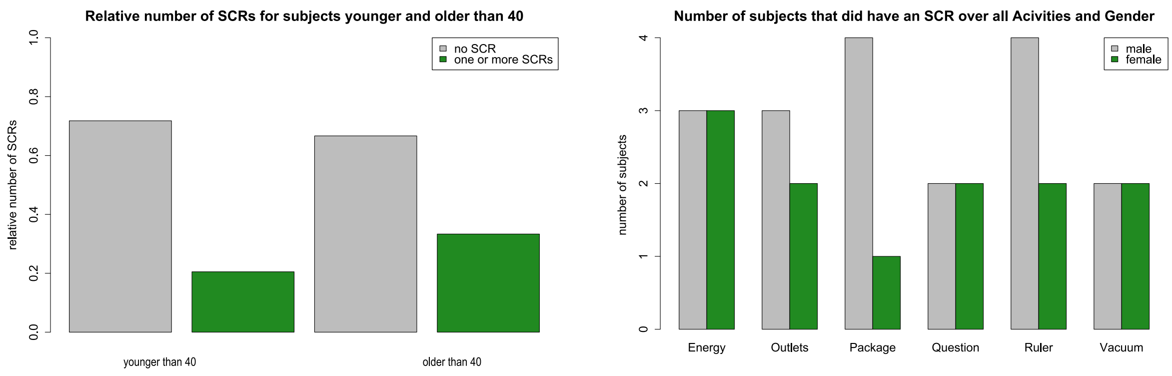
Since the variable SCRbool is a binary variable, the only method of choice is *logistic regression*. It does not require normal distribution of the variable nor homogeneity of variance [3] (as other methods do). And most importantly, this approach can also be used with categorical variables, such as SCRbool. Logistic regression determines, whether one or more predictor variables (in this case Activity, Presence, Gender, and Age) have a significant influence on the dependent variable (SCRbool).

All possible predictor variables were tried for significance with logistic regression. However, none of them was found significant. This means that none of these variables seem to have a significant influence on whether subjects show more (or less) SCRs.

5.2.2. Main Questionnaire

All 20 Subjects answered this questionnaire. Subjects were omitted automatically by the software in case of missing values (e.g. if a subject didn't answer the main Question for the Activity 'Vacuum').

[3] 'Homogeneity of variance' or 'homoscedasticity' for a data-set is present, if the variances of the variables do not significantly vary from each other.



(a) Age (b) Gender

Figure 5.3.: Both histograms show the proportion of subjects that did or did not have SCRs during any Activity, separated in groups of Age(a) and Gender(b)

Descriptive Statistics

As was done with the SC-data, first, the descriptive measures of the dependent variables will be examined before inferential methods are applied.

MainQ The *modal* of MainQ is 1 (representing the answer 'not at all'), which means, 1 is the value that was chosen most often. This, however, has little informative value, since the independent variables must be considered as well.

The frequency table of MainQ for each Activity respectively seems to support this assumption. As we can see in figure 5.4, for Activity 'Ruler' the modal is actually at 7, and for 'Vacuum' the modal is equally at 1 and at 7. It seems that depending on the Activity, answers for MainQ seem to vary immensely.

The *median* of MainQ lies at 2, which means, that half of the answers of MainQ lie at or below 2, and the other half above 2. However, again, if we consider the individual conditions of the variables, we get a very different picture. For example, the median of MainQ for 'Energy' and 'Vacuum' is 5, for 'Ruler' even 6.5. This distribution can be observed in the top-left bar-chart in Figure 5.5. Here, the mean answer for each Activity is presented and it can be seen that the before-mentioned three Activities have the highest mean answers.

So far we have only looked at the influence of Activity. Additionally, we can consider the independent variable Presence. For instance, for the condition 'Vacuum' x 'Present'[4] as well as 'Ruler' x 'Absent' the median is 7. This means that half of the subjects, that were 'Present' for the Activity 'Vacuum' and 'Absent' for the Activity 'Ruler' choose 7 in MainQ. This can again be observed in figure 5.5 in the top-right bar-chart. If we look at the *means* of MainQ for Activity x Presence, it seems that Presence might be a predictor for MainQ. Especially in the Activity 'Vacuum' the Presence seems to influence answers strongly.

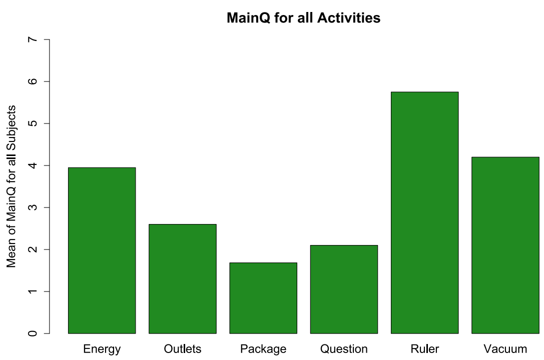
Looking at the bottom-left barchart, it appears that Gender does not have a strong influence on MainQ. Answers between male and female subjects do not seem to vary much.

Finally, the bottom-right bar-chart for Activity x Age shows that subjects older than 40 appear to rate slightly higher than subjects under 40 in all Activities but 'Package'. However, inferential methods are needed to confirm this assumption.

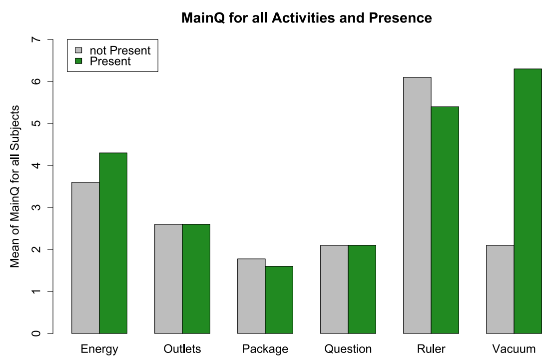
[4] For better understanding and legibility, interaction between variables such as the combination of all groups from Activity and Presence will be depicted in this way: $Activity \times Presence$ and respective values of those variables like this: $'Vacuum' \times' Present'$

MainQ/ Activity	1	2	3	4	5	6	7
Energy	4	2	1	2	8	1	2
Outlets	6	8	2	0	1	2	1
Package	13	4	0	0	1	1	0
Question	12	3	2	0	1	1	1
Vacuum	6	1	1	1	3	2	6
Ruler	1	0	2	0	4	3	10

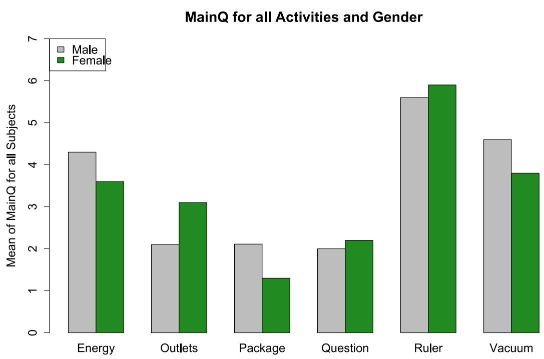
Figure 5.4.: Frequency table for all 7 answer possibilities in MainQ, split up over the six Activities. The results mentioned in the text are colored green.



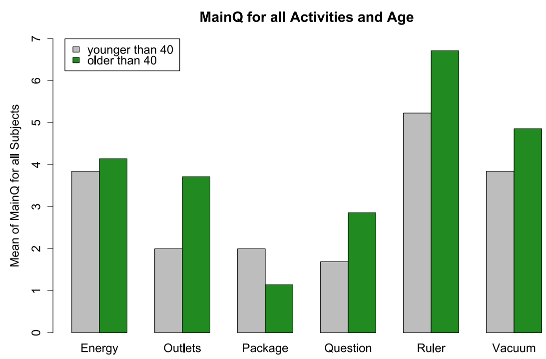
(a) Activity



(b) Presence

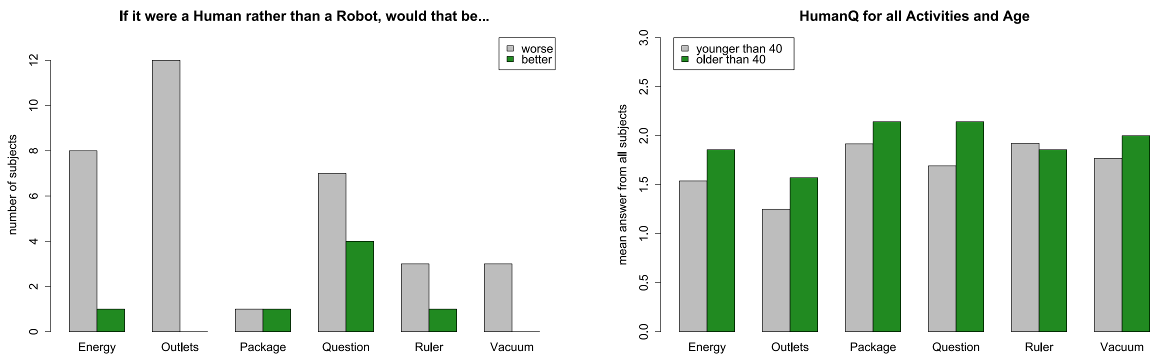


(c) Gender



(d) Age

Figure 5.5.: Mean answers in MainQ for the different Activities(a) in combination with Presence(b), Gender(c) and Age(d) respectively



(a) Activities

(b) Age

Figure 5.6.: The left barplot(a) shows HumanQ (excluding the value 'same') over all Activities. The other plot(b) shows the mean of HumanQ over all Activities and Age. For all Activities except 'Ruler', the group of older subjects has a higher mean than younger subjects

HumanQ The *median* for HumanQ is 2, meaning that most often subjects choose 'same' as their answer. This indicates that in most cases, it would not have made a difference whether a human or a robot would have been the one intruding. Under the different conditions of Activity these proportions change. For the Activity 'Outlets' the median is 1 ('worse'). This means that more than 50 percent of the subjects would have preferred a robot to charge its battery in their office than a human entering and charging a device.

In the left histogram of Figure 5.6, one can see the absolute number of subjects that either chose 'worse' or 'better' in HumanQ for each Activity. It shows that for every Activity 'worse' was chosen more often than 'better'. In the right histogram of the same figure, it is important to note that for all Activities except 'Ruler', the mean answers of subjects older than 40 are higher than that of younger subjects. This could imply that younger subjects would find it worse than older subjects, if a human and not a robot executed the Activity.

For Gender and Presence, no visible interesting effects could be found.

PresAbsQ For PresAbsQ the overall median is 1. This means that more than half of the subjects feel that Presence makes a difference. For the Activities 'Energy', 'Outlets', and 'Vacuum', the median is 1 again. This can be seen in the stacked bar-plot in 5.7 on the left, where the green bar is much higher than the grey one for those three Activities.

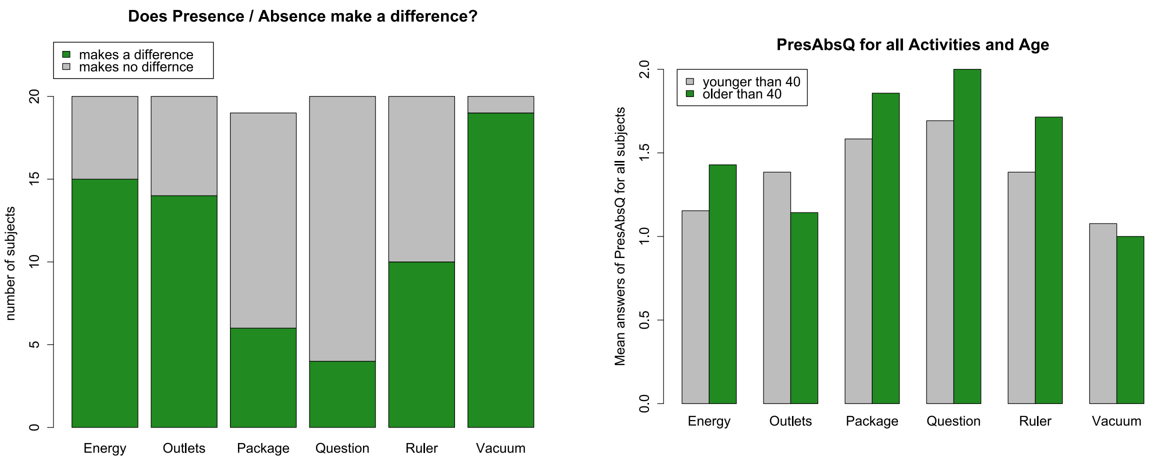
For some Activities, older subjects seem to care less about the Presence (e.g., 'Energy' and 'Question') and for some Activities younger subjects seem to care less about the Presence ('Outlets' and 'Vacuum') (therefore no barplot is presented).

In the bar-plot on the right one can see that Age does not seem to be an overall deciding factor. For Gender, the situation is similar.

However, whether these (lacks of) differences are significant needs to be seen. In order to confirm whether the reported influences of my variables are valid for the whole population, in the next section inferential methods will be used and results reported.

Inferential Statistics

As was done for the EDA-data, the dependent variables from MQ were tested for normal distribution and homogeneity of variance to determine which methods for inferential



(a) Activities

(b) Age

Figure 5.7.: PresAbsQ over all Activities (left). For the Activities Energy, Outlets and Vacuum the Presence seems to make a difference, on how the robot's behavior is perceived. The barplot for PresAbsQ for all Activities and Age (right) does not hint at any trend or influence of Age.

statistics could be used.

MainQ, **PresAbs!**, and HumanQ were all first tested for *normal distribution* using the Chi-square-adaption test also known as Pearson-Test. In this test all variables reached significant p-values <0.01. Therefore no normal distribution could be presumed.

Then, the data was tested for *homogeneity of variance* between groups using the Levene-test, which looks at the different variances of groups and tests whether those variances do not differ significantly from each other. For these tests results were ambiguous. For the subgroups of Presence in MainQ, for example, p was significant (0.04) and therefore heterogeneity of variance had to be assumed. Equally for the different Activities in MainQ and some groups of Activity x Age p was significant. For HumanQ and PresAbsQ results were similarly ambiguous. Therefore, instead of using different methods based on the Levene-test results, I decided to only use non-parametric tests for further evaluation, so that results could be compared. Non-parametric tests are alternatives to parametric tests such as t-test or analysis of variance (ANOVA), but with fewer prerequisites for the data (such as normal distribution or homogeneity of variance).

MainQ In order to determine statistically whether different groups vary significantly from each other, usually Analysis of Variance or similar methods are used. The Kruskal-Wallis-test is the non-parametric alternative for a one-factor Analysis of Variance when dealing with comparison between subjects. For a better overview, all results from this test for the three different questions are summarized in Figure 5.8.

Significant interaction of Activities x Presence for the Activity 'Vacuum', was found (with p***)[5]. This means that for the Activity 'Vacuum' the answers in MainQ from subjects that were 'Present' differ significantly from those that were 'Absent'.

Significant interaction was also found for Activity x Age for the Activities 'Outlets' (p*) and 'Ruler' (p**). In other words, subjects that were above 40 gave significantly different

[5] The three different significance-levels p<0.1, p<0.05 and p <0.01 will be coded from now on as p*, p** and p*** respectively

	Presence x Activity	Gender	Gender x Activity	Age	Age x Activity
MainQ	'Vacuum' - p***	n.s.	n.s.	n.s.	'Outlets' - p* 'Ruler' - p**
HumanQ	'Vacuum' - p*	n.s.	n.s.	p**	n.s.
PresAbsQ	'Ruler' – p*	n.s.	n.s	n.s.	n.s.

Figure 5.8.: This table shows the results from the Kruskal-Wallis-test for all three questions and the different independent variables. Significant results are highlighted in green

answers in MainQ for the Activities 'Outlets' and 'Ruler' than subjects that were younger than 40.

From the descriptive statistics one can assume that subjects younger than 40 rated significantly lower in both Activities. To confirm this assumption, a one-tailed Man-Whitney-test was done (the non-parametric alternative to a one-tailed t-test). The results confirm the assumption with p** for both Activities.

HumanQ For the variable HumanQ, the Activity x Presence interaction was found to be significant for 'Vacuum' (p*). Therefore, a one-tailed Man-Whitney test was done. This found that subjects who where present rated significantly higher than subjects who were absent. Looking at the total distribution, it was found that all subjects who were absent rated 2 meaning 'same'. Some subjects who were present rated 1 (worse). Also, it could be shown that Age has a significant effect (p**) on HumanQ. Again, from the descriptive statistics (right barplot figure 5.6) one can assume that younger subjects rated significantly lower than older subjects. The Man-Whitney test confirmed this (p**).

As was indicated in the descriptive statistics, no significant results could be found for Activity x Gender.

PresAbsQ Finally, the same tests were done for all independent variables and PresAbsQ. Here Activity x Presence interaction was also found significant for 'Ruler (p*). Again, a one-tailed test was done that confirmed, subjects who were absent rated less than present subjects (p**).

No significant interaction for Activity x Gender or Activity x Age could be found.

After looking at the differences *between* subjects, now the differences of groups *within* subjects will be analyzed. The non-parametric option for this is the Friedman-test. The only within-groups that exist for our three dependent variables are the different Activities. Again, all results are summarized in a table 5.9.

For MainQ, HumanQ as well as PresAbsQ variances between the different levels of Activity were all significant with $p < 0.01$, meaning, that the variance of two or more Activities for each variable varied significantly from each other!

As is common in statistical analysis, when inferential methods such as ANOVA deliver significant results, further tests are done, to determine, *which* groups differ from each other - these are so-called Post-Hoc tests. For those conditions that held only two groups (such as Presence, Gender and Age) this is not necessary, because it is clear which groups differ (i.e, 'Present' from 'Absent' etc.). For the Activities however, we need to look further. A non-

	MainQ	HumanQ	PresAbsQ
Activities	p***	p***	p***

Figure 5.9.: This table shows the results from the Friedman-test for all three questions. Answers to all three questions differ significantly from each other under the different Activities

MainQ - Activities	Energy	Outlets	Package	Question	Ruler
Outlets	0.6595	-	-	-	-
Package	0.0472 p**	0.5830	-	-	-
Question	0.0781 p*	1.0000	1.0000	-	-
Ruler	0.1247	0.0029 p***	0.0019 p***	0.0038 p***	-
Vacuum	1.0000	0.3652	0.0548 p*	0.1313	0.2651

Figure 5.10.: This table shows results from the Wilcoxon-test, where answers of MainQ for each Activity were compared to all others. Green cells show, where answers differed significantly from each other

parametric alternative to t-tests that compare within-subjects data[6] is the Wilcoxon-Test. This test was used on all three dependent variables:

MainQ For the variable MainQ all Activities were compared to each other; as can be seen in table 5.10 all Activities differ significantly at least from one other Activity. Since the Wilcoxon-Tests were two-tailed, it is not possible to say *how* the Activities differ from each other, only that they do. For example, the results show that participants' answers for 'Energy' significantly differed from their answers for 'Package' (with $p < 0.05$). In order to see whether those answers were higher or lower in the Activity 'Package', individual one-tailed Wilcoxon-tests were done. Each Activity that differed significantly from another was considered and based on the data from the top-left histogram in Figure 5.5, the hypothesis was either that activity A had significantly higher or lower values than Activity B. The results of all tests are presented hereafter, with the first Activity always having significantly lower values than the second: Package x Energy (p***), Question x Energy (p***), Outlets x Ruler (p***), Package x Ruler (p***) and Question x Ruler (p***).

[6] Comparing within-subject data means that data from one subject is compared with different data from the same subject. For example, answers from one subject for Activity 'Ruler' are compared with the same subject's answers for Activity 'Outlets'

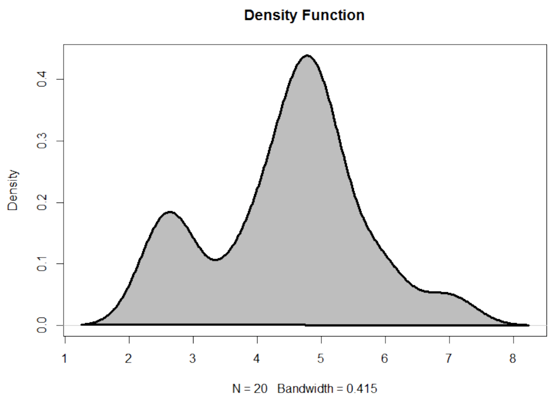


Figure 5.11.: This figure shows a density graph of Score. It shows that the distribution seems to be bi-modal, with the higher of the two peaks between 4 and 5

HumanQ For the variable HumanQ the Wilcoxon-test was done again for all Activities. Here, only 'Outlets' differed significantly (p**) from 'Vacuum' and 'Package. One-tailed Wilcoxon-tests showed that 'Outlets' got significantly lower values (1,2) than the other two Activities (p***). This means that participants felt it far worse if a human would have charged a device in their office than if a human would have vacuum-cleaned the floor or brought a package.

PresAbsQ For PresAbsQ the same comparison between the Activities found several significant differences: 'Question'x'Energy' and 'Question'x'Outlets' (both p**), 'Vacuum'x'Package' and 'Vacuum'x'Question' (both p***) and also 'Vacuum'x'Ruler' (with p*). One-tailed tests showed, that 'Energy', 'Vacuum' and 'Outlets' respectively had significantly (p***) lower rates than the other Activities. These results indicate that participants found that for the three mentioned Activities the presence of the territory owner would have mattered more than for the other Activities on how the robot's behavior was perceived.

5.2.3. General Questionnaire

Descriptive Statistics

As was mentioned already in Chapter 4, due to my study design no direct comparison to the results from Wollman and Kelly are possible. Therefore, the results of the General Questionnaire can only be reported as a basis for later studies and with respect to the independent variables Gender and Age.

In GQ there are 8 items alluding to the same question: 'How much does territory intrusion affect a person'. As mentioned in Preparation of the Data (5.1), the mean over the eight questions was calculated and saved as the main and only dependent variable 'Score'. Score can be treated as interval-scaled. Therefore, on top of the descriptive measures such as modal and median, mean and standard deviation can be examined as well. The only independent variables in this questionnaire are Age and Gender. (Activity and Presence were not applicable because this questionnaire was asked independently of the audio-texts).

The mean of Score is 4.2125, for an answering range between 1 and 7 this is slightly above the middle. The variance is 1.32 and the standard deviation lies at 1.152. The general distribution as a density function can be seen in figure 5.11. The distribution seems to be bi-modal, meaning it has two peaks.

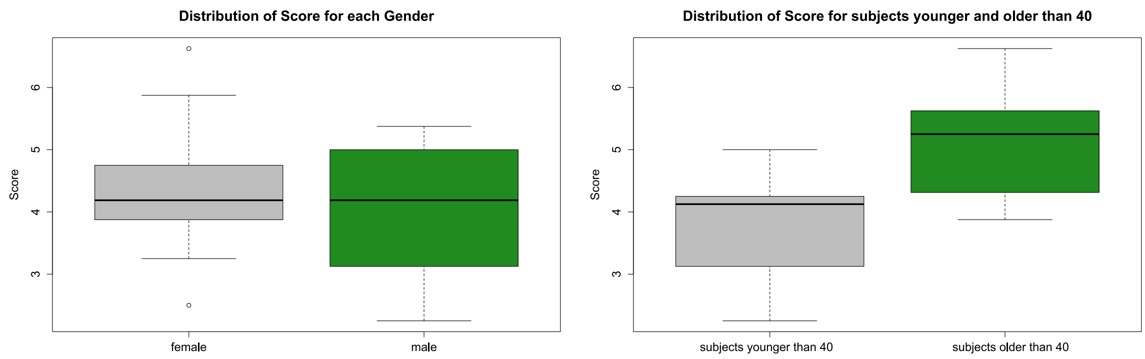


Figure 5.12.: These boxplots show the distribution of Score for the subgroups of Gender(left) and Age(right) respectively

If we look at the distribution of Score between male and female subjects, the means are close to each other, but the variance is different. This can be seen in the box-plots in figure 5.12. Both medians lie slightly above 4. Also, the distribution of the male score seems slightly skewed to the left.

Looking at the Score distribution under the conditions of Age (figure 5.12, right), it is interesting to note that the median and the box in total of subjects older than 40 lies distinctly above the box of subjects younger than 40. This means that most subjects older than 40 have in general a higher Score than subjects under 40.

Inferential Statistics

As was done for the variables from MQ, Score was tested for normal distribution and homogeneity of variance. Two tests were used for determining *normal distribution* with the following results:

- Lilliefors-test, with p=0.44999
- Shapiro-Wilk-test with p=0.94

Since both tests were not significant, normal distribution can be assumed.

For testing on *homogeneity of variance*, again the Levene-test was used for the subgroups of Gender and Age. For both tests p was not found significant and therefore homogeneity of variance could be assumed. For these reasons, non-parametric methods were unnecessary and normal methods could be used.

Differences between the Score of male and female subjects using a t-test were not found significant.

However, a significant effect for Age was found with $p < 0.01$. This means that subjects under 40 differed significantly in their answers from subjects older than 40. Because it was only examined *whether* the groups differed (two-tailed t-test) and not *how* (one-tailed t-test), it is now interesting to look at the means of the two groups: Subjects under 40 had a mean of 3.74, subjects older than 40 a mean of 5.08. This indicates, that older subjects in general voted higher on the General Questionnaire than younger subjects. To confirm this hypothesis, a one-tailed t-test was done with the alternative hypothesis that the Score for subjects over 40 is higher than for subjects under 40. The t-test was found significant, with $p < 0.01$.

In the next chapter, the results will be discussed, future tasks and questions identified and possible conclusions drawn.

6. General Discussion

In the following sections, the results of the study will be summarized and possible conclusions will be drawn with respect to the hypotheses from the introduction. Since no significant results were found for EDA, only the MQ and GQ will be discussed in this section. Afterwards, limits of the study will be discussed and finally, consequential future tasks are listed.

6.1. Discussion

In this section, I try to interpret the results from my study with respect to the hypotheses from Chapter 1 and the four independent variables. Altogether, six main conclusions can be drawn.

6.1.1. Activity matters

Hypothesis H2 said the type of activity a robot executes effects how strong his intrusion will be perceived by the owner. The results from Chapter 5 confirmed this repeatedly. For the answers in MainQ, significant differences existed for the different Activities. Every Activity differed significantly from at least one other Activity. It supports the hypothesis that subjects feel less or more infringement, depending on the reason why a robot enters their office. This is important. That the Activities differ from each other implies that Activities exist which were perceived more negatively. A social robot should know about these differences to adapt its behavior accordingly. Furthermore, the descriptive statistics show and the results imply that some Activities exist which seem to bother humans far less (bringing a package, for example). These activities seem to entail a far lower cost in socially acceptable behavior.

One could further argue that Activities which include bringing or giving something to the territory owner in his territory are received better than Activities which take something. For example, the Activities 'Ruler' and 'Energy' got significantly higher ratings than 'Question' and 'Package' (p***). In the former activities, something is taken from the owner (such as the Light or their Ruler), whereas the Package brings something to the owner, and the Question-Activity at least delivers information.

To summarize, Activity does influence the reaction of subjects toward robotic intrusion, and Hypothesis H2 is roughly confirmed. This makes sense. The activity that someone (or something) is executing is always connected to a motivation or an intention *why* he/she is executing it. In social interaction it is often the intention behind an action, and not the action itself that decides whether the behavior is perceived as positive and polite or rather rude and improper.

6.1.2. Presence also matters

Hypothesis H3 claimed that whether someone is present or absent can determine how the intrusion of a robot is perceived. At least in combination with the activity the robot is executing this hypothesis can be confirmed.

The results from PresAbsQ, which were included in the questionnaire to examine this variable, are very clear. As was reported in Chapter 5, the median for PresAbsQ is 1. This means that at least half of the answers to the question whether Presence would have made a difference were answered positively. The tests confirmed that there were significant differences for the Activities. One-tailed tests further showed that 'Vacuum' had significantly lower values than 'Package', 'Ruler' and 'Outlets'. This means that for 'Vacuum' (and also 'Energy') Presence can make a huge difference to whether subjects find the robot's behavior acceptable. This is not necessarily surprising. Vacuum-cleaning is an activity that can disrupt someones concentration and can be perceived as annoying or disturbing. That subjects feel their Presence makes a difference on how they perceive the robot's behavior seems logical.

In MainQ the predictor Presence was also found significant for 'Vacuum'. This means that subjects who were present while the robot entered the office and started vacuum-cleaning rated differently than subjects who were absent. Again, this is not surprising. Important to note, however, is that subjects who were absent rated rather positively. It was mentioned that the modal of MainQ for this Activity was equally at 1 and 7. There were just as many subjects that seemed fine with the robot's behavior then there were subjects who didn't. Subjects who where absent apparently had no problem at all with the robot entering their office and vacuum-cleaning it.

To conclude, for socially acceptable behavior, it is essential that robots consider the whereabouts of the territory owner/s. Hypothesis H3 could at least in part be confirmed. Significant interaction between the Activity of the robot and the Presence of the territory owner exists.

6.1.3. Age should be considered

The results have shown that Age can influence the reaction towards robotic intrusion. The answers in MainQ from older people differed significantly from answers from younger people - at least for distinct Activities. When the robot charged himself ('Outlets') and when he entered to borrow a ruler ('Ruler'), subjects older than 40 seemed to rate much higher than subjects younger than 40. This was confirmed by the one-tailed Wilcoxon-test.

Results from the General Questionnaire support this. Again, the evaluation showed that older subjects rated significantly higher than younger subjects.

It leads to the conclusion that older subjects are more sensitive to the intrusion of robots than younger subjects. One possible explanation for this is the level of *experience* people have with robots and technology in general. In the study from Takayama and Pantofaru (2009), it was found that subjects with less experience with robots showed different proxemic behavior than more experienced people. In their paper only personal space behavior was tested. This might be true, however, for any interaction with robots. It would be interesting to investigate the interaction of experience and perceived infringement.

6.1.4. Gender needs further investigation

Finally, it is worth mentioning that the Gender was not found to be a predictor for territory infringement. Neither in EDA, the Main Questionnaire nor in the General Questionnaire was Gender found to be a significant influence. This is slightly surprising. It is common knowledge that differences exist between men and women for many situations. Men and women often handle social situations differently - but not always. In their study on temporary territories in the library, Tailor and Brooks reported that male and female subjects were "equally likely to regain their original seat" back (Taylor and Brooks, 1980, p. 142).

It seems equally possible that male and female subjects show the same amount of reaction towards robotic intrusion. On the other hand, it is conceivable that in real live interaction, territorial behavior would prove significantly different. This is certainly worth looking into in consecutive studies.

6.1.5. Subjects perceive robotic infringement

Hypothesis H1 claimed that humans will perceive robotic territorial intrusion. Taking all the results and implications from above into account the underlying question (and hypothesis H1) of this study can be answered carefully - subjects do perceive robotic territorial intrusion into their office!

The results from the descriptive statistics for MainQ show that subjects not only react differently towards the Activities, but that some of those reactions are actually negative. For example, the reported median for Activities 'Energy', 'Vacuum' and 'Ruler' was equal to or above 5. For the interactions of 'Vacuum $\times$ 'Present' and 'Ruler' $\times$ 'Absent', the median was 7. With 7 representing the most negative answer ('not ok at all'), this shows that subjects were displeased with the robot's behavior. Subjects can and do react towards a robot's intruding behavior, always depending on the Activity and in part on the Presence and Age of the owner.

But would they feel the same way if it were a human?

6.1.6. Human or Robot - who intrudes more?

The general results for HumanQ are easy to interpret. The median is 2, meaning that most subjects over all conditions did not think a human would have been better or worse. Looking at the distinct Activities however, the distribution changes.

Answers in the Activity 'Outlets' differ significantly from 'Vacuum' or 'Package'. From Figure 5.6, we can conclude that 'Outlets' had a lower rating than 'Vacuum' or 'Package', and for both cases one-tailed tests confirmed this. The natural conclusion is that the Activity of the robot determines whether subjects see a difference in the nature of the intruder. For some Activities (e.g., 'Outlets'), intrusion would be considered worse if it were a human and not a robot. Furthermore, in all Activities except for Package, 'worse' was chosen more often than better (although 'same' was chosen most often). This indicates that if a distinction between robot and human is made, the intrusion by a human is almost always considered *worse*.

A possible explanation is that humans are expected to always respect the social rules of territory. If a human and not a robot intrudes into a territory while executing a certain activity, the motivation is of essence. In other words, humans seem to attribute more social awareness and responsibility towards humans than they do towards robots. If a human breaches a social territory rule, it is far more likely that he/she does this intentionally. Possibly a human is perceived far more threatening or disrespectful than a robot.

This has important consequences. Conflicting tasks which might jeopardize or at least impair social relationships between colleagues could be executed by robots. At least if the conflict is founded in the human entering the territory, and not in the Activity itself.

Especially for the Activity 'Vacuum', the responses of participants who were present differed significantly from those who were absent. The one-tailed test showed that subjects who were present rated significantly lower (1 or 2) than subjects who were absent (all subjects rated 2 here). This indicates that the participants would find it much worse if a person and not a robot had entered their office to vacuum while they were present. This may not be surprising. Entering an office and starting to make loud noise without asking the owner's permission can be seen as very impolite. That this would be worse for a person than a robot, again, indicates that subjects would perceive a much stronger violation of their social rights with a human intruder.

Finally, the evaluation showed that subjects younger than 40 rated significantly different from older subjects in the Activity 'Vacuum'. However, it could not be determined whether they rated higher or lower, only that they rated differently. This calls for further investigation. If older people would perceive a human as less infringing than a robot, for instance, this should be considered for the robot's field of operation.

6.2. Limits of the Study

Although significant results were found, and some of the fundamental questions of this study could be answered, it is important to consider the limits and flaws as well - as a form of self-reflection as well as a way to improve future studies.

Using imaginary infringement rather than real live experiences is the core of this study design. In Chapter 4 it was established why this approach was chosen. Nonetheless, simulation can hardly substitute real live experiments. This is one limit of the study and the lack of results from one instrument - EDA - could be due to this design.

The results from the EDA-evaluation are clear - none of the tests were significant. The only definite conclusion that can be drawn is that no significant number of skin conductance responses was measured. Interpretation of these results, however, is manifold: The results do not imply that subjects didn't have a *reaction* towards the infringement.

Besides the fact that imaginary infringement might provoke no reaction at all, several other explanations are possible:

- Subjects did react to the imaginary intrusion, however, skin conductance is not fit to measure those reactions.
- Subjects did react, however, the hard- and software were not able to detect those reactions.
- Subjects did react, but the amplitude or latency set as an exclusion factor was too restrictive
- Although subjects perceived infringement, since it was imaginary, no physiological reaction took place. Possibly a real live experiment would have produced different results.

It is up to consecutive studies to determine whether real live infringement to robotic territory intrusion can be measured with EDA.

Finally, the validity of the other two instruments that I used has not been established. Although the questionnaire from Wollman and Kelly was validated, my adapted version of this questionnaire still needs validation. Furthermore, the Main Questionnaire of this study included only one item (MainQ) to measure the central question - "How much did subjects mind the robot's intrusion". As is common for Likert-scales, any question should be measured by several items.

6.3. Conclusions

Due to the scope of the study, many aspects and questions were left open that should be considered in the future. On the one hand, there are limits to the study (other than those already mentioned) that might be overcome in follow-up studies. On the other hand, the results opened new questions that are worth looking into.

Following this rather introductory study on territory spaces in HRI with a *simulation* of robotic intrusion at its core, a live study is needed. For one, it would be interesting to confirm the significant results from this study and investigate further influences. Also, the approach to measure infringement with EDA should be employed again, to see whether real live infringement can be measured with EDA.

As was mentioned in the discussion on Activity, the results hint at a possible influence of type of activity. Is it possible that certain categories of Activities exist that influence the level of infringement subjects feel during robotic intrusion? It stands to reason that Activities which benefit the territory owner might be perceived as far less infringing than other activities. This is certainly worth looking into. If Activities could be sorted into categories of higher and lower social costs, implementation could become much easier.

Many reasons were given for why the workplace is an environment of interest for the study of territory space and HRI in general. Nonetheless, other environments exist that would also be interesting to look at with respect to territory space. Primary spaces such as the home are important environments where robots will be introduced in the future. It was discussed that Age seems to be an influencing factor on robotic intrusion, and the converse argument is that robotic intrusion with older people should be looked at more closely. The environment of a nursing home could be especially interesting in this regard.

This leads to another matter of interest. The discussion on Age, which proved to be a significant influence, opens the question of 'experience' and perceived infringement. Perhaps participants with a higher level of experience with robots and technology in general perceive less (or more) infringement. If so, this might impact the field of application for the robot or the behavior it should conduct towards different people.

Another very interesting aspect that this study has only begun to answer is whether robots actually provoke less infringement or more infringement than humans. As was mentioned already in the discussion, this knowledge can have practical advantages. Not only with respect to avoiding robotic intrusion but also towards having robots rather than humans do the intrusion. If robots, at least in certain situations (or for certain activities), are not perceived as infringing this might be another application area. If, for instance, workers perceive strong violation of their privacy and territorial rights when a colleague or administration staff member needs to enter their office without permission, robots could take over and say, deliver a package or get the full trash can. In the future, it would be interesting to look further into the *differences* and *similarities* of human and robotic intrusion. Therefore, a study design is necessary where both humans and robots intrude on territory spaces.

The design of this study did not support the idea of different social roles a robot could represent. In the definition of territory space in Chapter 2, it was stated that a claim on a territory relates to the social role that a person embodies. A policeman has access to a private home under certain circumstances and a woman can enter the woman's bathroom without further social impact. Therefore, it would be interesting to know whether a robot can be perceived to embody a social role as well. For example, for the personal robot of the chairman, other rights concerning entering a worker's office might apply than they would for a robot belonging to the administration or to the colleague from next door. *Who* the robot works for might be an additional predictor to *what* activity he is executing during intrusion.

Another interesting aspect arises when the focus shifts to the implementation of territory-conform behavior. If it is indeed necessary to have robots be aware of different territory spaces, how could this social behavior be implemented? Robots would need to recognize a territory space, be aware of the owners and the social norms that guide entrance and internal behavior. Would traditional territory markers that humans can recognize suffice for robots to determine existence and shape of a territory, or are other mechanisms needed to implement successful territory recognition? Could methods used for personal space recognition or activity space recognition work for this concept as well? If not, does a necessity exist for a fundamental approach for implementing different social spaces with one concept?

To conclude, many questions were opened in this study and some were answered. It seems that humans do indeed perceive some form of robotic territory infringement at the workplace. Two of the three instruments used in this study measured some form of negative reactions towards robot intrusion. On top of that, the different predictors Activity, Presence, and Age were identified to influence subject's attitude towards robotic infringement. Now it is up to future studies to confirm these results and find answers and solutions to the question of implementation.

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List of Abbreviations

HHI Human-Human Interaction

HRI Human-Robot Interaction

MQ Main Questionnaire

GQ General Questionnaire

EDA Elektrodermal Activity

SC Skin Conductance

SCL Skin Conductance Level

SCR Skin Conductance Response

DDA Decomposition of skin conductance data by means of non-negative deconvolution

SCRbool Skin Conductance Responce Boolean Variable

PresAbsQ Presence-Absence Question

MainQ Main Question

HumanQ Human Question

ANOVA Analysis of Variance

Kursiv = Vom Sprecher vorgelesen

Anweisung :
(AUDIO)
Nachfolgend wird dir ein fiktives Szenario beschrieben, welches in der Zukunft spielt und einen typischen Arbeitstag von dir beschreibt. Stell dir dazu bitte vor, dass in deinem Arbeitsumfeld zukünftig Roboter eingesetzt werden, die verschiedene Aufgaben zu erledigen haben, oder Mitarbeiter bei ihrer Arbeit unterstützen. Die Roboter sehen so aus, wie auf dem Bild, das dir gezeigt wurde.

Stell dir vor, du arbeitest bei einer Firma deiner Wahl, und hast ein eigenes Büro, das dir allein zur Verfügung steht. Falls du tatsächlich ein eigenes Büro hast, nimm dieses bitte als Beispiel.
Bitte denk darüber nach, wie dein Büro aussehen würde. Wie sieht dein Schreibtisch aus, dein Schreibtischstuhl? Sind Fotos deiner Familie und Freunde aufgestellt oder hängen Bilder deiner Lieblingskünstler an der Wand?
Befinden sich Regale in deinem Büro, ein Besprechungstisch? Eine eigene Garderobe oder vielleicht ein Radio von zu Hause für deine Pausen?
Bitte denk kurz darüber nach wie dein Büro aussehen würde.

Bitte höre jetzt der Geschichte zu, und versuche dich in sie hineinzuversetzen. Du kannst dazu die Augen schließen.

Kursiv = Vom Sprecher vorgelesen

(AUDIO)
So wie jeden morgen kommst du pünktlich bei deiner Arbeit an, wirst von einem ***Serviceroboter R1****, und dem diensthabenden Empfangspersonal im Eingang begrüßt. Du fährst mit dem Fahrstuhl in deinen Flur, gehst in dein Büro, machst das Licht an, legst deinen Mantel auf einen der Stühle und fährst deinen Computer hoch.*
Du setzt dich an deinen Schreibtisch, und beginnst, alle neuen Emails durchzusehen, die für dich angekommen sind.

Der Roboter ***R2 (anwesend)*** *muss für eine seiner Aufgaben* ***Kontakt*** *zu dir aufnehmen, um dich etwas zu fragen.*
Er fährt zu deinem Büro, zu dem die Tür offen steht, und erkennt, dass du anwesend bist. Er fährt hinein und spricht dich an.

Nachdem du seine Frage beantwortet hast, wendest du dich deiner Arbeit zu und beginnst, auf die wichtigsten Emails zu antworten. Du arbeitest eine Weile, bis du, so wie jeden Vormittag gegen 11, in die Mitarbeiter-Küche gehst, um dir einen Kaffee zu machen.

In der Zwischenzeit fährt der Roboter ***R3 (abwesend)*** *an deinem Büro vorbei. Er ist unter anderem dafür zuständig,* ***Energiesparmaßnahmen*** *auf deinem Flur umzusetzen,*
Deine Tür steht offen und er erkennt, dass das Deckenlicht an ist, obwohl genug Licht durch das Fenster hereinkommt. Er fährt in dein Büro und schaltet das Licht aus.

Später, nach einem Gespräch mit deinem Chef kommst du in dein Büro zurück. Du stellst fest, dass der Roboter ***R4 (abwesend)*** *den Boden* ***gesaugt*** *hat. Du setzt dich an deinen Schreibtisch und beginnst mit der neuen Aufgabe, die dein Chef dir übertragen hat. Während der Arbeit fällt dir auf, dass du noch eine Mappe mit Dokumenten zu deiner Kollegin bringen musst. Du rufst einen der Roboter (****R5****) zu dir, und übergibst ihm die* ***Mappe*** *und den Auftrag, sie zu deiner Kollegin zu bringen.*

Du gehst zurück an die Arbeit und stellst die Aufgabe für deinen Chef fertig.
Als dir auffällt, dass deine Blumen die Köpfe hängen lassen stehst du auf und fängst an, sie zu gießen. Der Roboter ***R6 (anwesend)*** *sucht währenddessen nach einer* ***Steckdose****, um seinen Akku aufzuladen.*
Er erkennt, dass es in deinem Büro mehrere zugängliche Steckdosen gibt, also fährt er hinein und schließt sich an die Steckdose an.

Es ist Mittagspause und du gehst mit ein paar Kollegen in die Kantine, wo du dir eine leckere Hauptspeise und ein Dessert genehmigst. Nach dem Essen kommt einer der ***Kantinen-Roboter (R7)*** *und räumt dein Tablett und das deiner Kollegen weg.*
Zur gleichen Zeit soll der Roboter ***R8 (abwesend)*** *von einem Mitarbeiter, ein* ***Paket*** *zu dir bringen. Er fährt zu deinem Büro, erkennt, dass deine Tür offensteht und fährt rein, um das Paket auf deinem Schreibtisch abzulegen.*

Nach der Mittagspause kommst du zurück in dein Büro und kümmerst dich um das Paket und ein paar neue Emails, die in der Zwischenzeit eingetroffen sind.
Eine deiner Kolleginnen im Stock unter dir wird bald 50, und du hast den Auftrag, ein Geschenk für sie zu bestellen, also suchst du im Internet nach guten Geschenkideen.

Der Roboter ***R9 (anwesend)*** *hat den Auftrag bekommen, ein* ***Lineal*** *für einen Mitarbeiter zu*

besorgen.
Er erkennt, dass in deinem Büro, wo die Tür offen ist, ein passendes Lineal auf dem Beistelltisch liegt. Er fährt in dein Büro und nimmt das Lineal mit.

Später, nach einem spontan einberufenen Meeting mit der Vorsitzenden der Finanzabteilung kommst du in dein Büro zurück und stellst erleichtert fest, dass es schon Zeit ist, nach Hause zu fahren.
Du fährst deinen PC runter, ziehst deinen Mantel über, ~~schließt dein Büro ab~~ und machst Feierabend.

Kursiv = Vom Sprecher vorgelesen

(AUDIO)
So wie jeden morgen kommst du pünktlich bei deiner Arbeit an, wirst von einem ***Serviceroboter R1*** *und dem diensthabenden Empfangspersonal im Eingang begrüßt. Du fährst mit dem Fahrstuhl in deinen Flur, gehst in dein Büro, machst das Licht an, hängst deinen Mantel auf und fährst deinen Computer hoch. Du setzt dich an deinen Schreibtisch, und beginnst, alle neuen Emails durchzusehen, die für dich angekommen sind.*

Du beginnst, auf die wichtigsten Emails zu antworten. Du arbeitest eine Weile, bis du, so wie jeden Vormittag gegen 11, in die Mitarbeiter-Küche gehst, um dir einen Kaffee zu machen.

Der Roboter ***R2 (abwesend)*** *muss für eine seiner Aufgaben* ***Kontakt*** *zu dir aufnehmen, um dich etwas zu fragen.*
Er fährt zu deinem Büro, zu dem die Tür offen steht, und erkennt, dass du nicht da bist. Er fährt in dein Büro und wartet dort auf dich.
Nachdem du zurückgekommen bist und seine Frage beantwortet hast, wendest du dich wieder der Arbeit zu.

In der Zwischenzeit fährt der Roboter ***R3 (anwesend)*** *an deinem Büro vorbei. Er ist unter anderem dafür zuständig,* ***Energiesparmaßnahmen*** *auf deinem Flur umzusetzen.*
Deine Tür steht offen und er erkennt, dass das Deckenlicht an ist, obwohl genug Licht durch das Fenster hereinkommt. Er fährt in dein Büro und schaltet das Licht aus.

Nach einiger Zeit fällt dir auf, dass es Zeit für das wöchentliche Gespräch mit deinem Chef ist, und du machst dich auf den Weg zum Büro deines Chefs.
Der Roboter ***R4 (abwesend)*** *sucht währenddessen nach einer* ***Steckdose****, um seinen Akku aufzuladen.*
Er erkennt, dass es in deinem Büro mehrere zugängliche Steckdosen gibt, also fährt er rein und schließt sich an die Steckdose an.

*Später, nach dem Gespräch mit deinem Chef kommst du in dein Büro zurück, setzt dich an deinen Schreibtisch und beginnst mit der neuen Aufgabe, die dein Chef dir übertragen hat. Während der Arbeit fällt dir auf, dass du noch eine Mappe mit Dokumenten zu deiner Kollegin bringen musst. Du rufst einen der Roboter (****R5****) zu dir, und übergibst ihm die* ***Mappe*** *und den Auftrag, sie zu deiner Kollegin zu bringen.*

Du gehst zurück an die Arbeit und stellst die Aufgabe für deinen Chef fertig.
Als dir auffällt, dass deine Blumen die Köpfe hängen lassen stehst du auf und fängst an, sie zu gießen. Währenddessen fährt der Roboter ***R6 (anwesend)*** *in dein Büro, und beginnt den Boden zu* ***saugen****.*
Du gehst zurück an deine Arbeit.

Es ist Mittagspause und du gehst mit ein paar Kollegen in die Kantine, wo du dir eine leckere Hauptspeise und ein Dessert genehmigst.Nach dem Essen kommt einer der ***Kantinen-Roboter (R7)*** *und räumt dein Tablett und das deiner Kollegen weg.*

Du kehrst in dein Büro zurück und kümmerst dich um ein paar neue Emails, die in der Zwischenzeit angekommen sind. Eine deiner Kolleginnen im Stock unter dir wird bald 50, und du hast den Auftrag, ein Geschenk für sie zu bestellen, also suchst du im Internet nach Geschenkideen.
Zur gleichen Zeit soll der Roboter ***R8 (anwesend)*** *für einen Mitarbeiter, ein* ***Paket*** *zu dir bringen.*
Er fährt zu deinem Büro, erkennt, dass deine Tür offensteht und fährt rein, und übergibt dir das

Paket.

*Später wirst du spontan zu einem Meeting mit der Vorsitzenden der Finanzabteilung gerufen. In der Zwischenzeit hat der Roboter **R9 (abwesend)** den Auftrag bekommen, ein **Lineal** für einen Mitarbeiter zu besorgen. Er erkennt, dass in deinem Büro ein passendes Lineal auf dem Beistelltisch liegt. Er fährt in dein Büro und nimmt das Lineal mit.*

Nach dem Meeting kommst du in dein Büro zurück und stellst erleichtert fest, dass es schon Zeit ist, nach Hause zu fahren. Du fährst deinen PC runter, ziehst deinen Mantel über und machst Feierabend.

Kennzeichen ____________

Fragebogen Teil I

Erinnere dich bitte nochmal an die Szene zurück, wo...
… der Roboter R2 dich etwas fragen muss, und in dein Büro fährt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du abwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R3, der für Energiesparmaßnahmen zuständig ist, in dein Büro fährt und dein Licht ausschaltet.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

Kennzeichen ____________

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du anwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R4 in dein Büro fährt und staubsaugt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du anwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kennzeichen ____________

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R6, der nach einer Steckdose sucht, sich in deinem Büro auflädt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du abwesend wärst?	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Kennzeichen ___________

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R8 in dein Büro fährt und dort ein Paket ablegt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du anwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R9 in dein Büro fährt und ein Lineal mitnimmt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

Kennzeichen ____________

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du abwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern,
womit du beschäftigt warst,
als der Roboter dieses Verhalten
zeigte?

Kennzeichen ____________

Fragebogen Teil I

Erinnere dich bitte nochmal an die Szene zurück, wo...
… der Roboter R2 dich etwas fragen muss und in dein Büro fährt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du anwesend wärst?	☐	☐	☐

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Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R3, der für Energiesparmaßnahmen zuständig ist, in dein Büro fährt und dein Licht ausschaltet.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

Kennzeichen ____________

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du abwesend wärst?	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R4, der nach einer Steckdose sucht, sich in deinem Büro auflädt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du anwesend wärst?	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
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Kennzeichen ____________

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R6 in dein Büro fährt und staubsaugt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du abwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Kennzeichen ____________

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R8 in dein Büro fährt und ein Paket an dich übergibt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du abwesend wärst?	☐	☐	☐

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Erinnere dich bitte nochmal an die Szene zurück, wo...
...der Roboter R9 in dein Büro fährt und ein Lineal mitnimmt.

	Absolut in Ordnung						Auf keinen Fall in Ordnung
Dieses Verhalten finde ich....	☐	☐	☐	☐	☐	☐	☐

Kennzeichen ____________

	Ja, das würde ich schlechter finden	Ja, das würde ich besser finden	Nein, das macht keinen Unterschied
Würde es einen Unterschied machen, wenn du anwesend wärst?	☐	☐	☐
Würde es einen Unterschied machen, wenn ein Mitarbeiter und nicht ein Roboter das gleiche Verhalten gezeigt hätten?	☐	☐	☐

Kannst du dich noch erinnern, womit du beschäftigt warst, als der Roboter dieses Verhalten zeigte?

Kennzeichen ___________

Fragebogen Teil II

Alter: ________________ männlich ☐ weiblich ☐

Wie sehr würde es dir etwas ausmachen, wenn ein Roboter...

1. ...deine persönlichen Gegenstände umräumt ?

Absolut in Ordnung ☐—☐—☐—☐—☐—☐—☐ Auf keinen Fall in Ordnung

2. ...dein Arbeitsmaterial für jemand anderen holen würde?

Absolut in Ordnung ☐—☐—☐—☐—☐—☐—☐ Auf keinen Fall in Ordnung

3. ...deine Arbeitsmaterialien umräumen würde?

Absolut in Ordnung ☐—☐—☐—☐—☐—☐—☐ Auf keinen Fall in Ordnung

4. ...Arbeitsmaterialien aus deinem Büro nehmen würde, wenn sie auch öffentlich zugänglich wären?

Absolut in Ordnung ☐—☐—☐—☐—☐—☐—☐ Auf keinen Fall in Ordnung

Kennzeichen ___________

Wie sehr würde es dir etwas ausmachen, wenn...

5. ein Roboter etwas auf deinem Schreibtisch ablegen würde?

   Absolut in Ordnung ☐ — ☐ — ☐ — ☐ — ☐ — ☐ — ☐ Auf keinen Fall in Ordnung

6. ein Roboter, der für jemanden arbeitet, den du nicht magst, dein Büro betritt?

   Absolut in Ordnung ☐ — ☐ — ☐ — ☐ — ☐ — ☐ — ☐ Auf keinen Fall in Ordnung

Wie sehr würde es dir etwas ausmachen, wenn ein Roboter...

7. ...in dein Büro fährt, ohne sich vorher bemerkbar zumachen?

   Absolut in Ordnung ☐ — ☐ — ☐ — ☐ — ☐ — ☐ — ☐ Auf keinen Fall in Ordnung

8. ...in dein Büro fährt, während du abwesend bist?

   Absolut in Ordnung ☐ — ☐ — ☐ — ☐ — ☐ — ☐ — ☐ Auf keinen Fall in Ordnung

Declaration of Authorship - Eigenständigkeitserklärung

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(Kim Antonia Reichert, Hamburg, August 21, 2013)