Moving with Style: Classifying Human and Robot Movement at Home

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Abstract—A robot moving in the home is a new experience for most people. Classifying the different ways that humans and robots move together can help in designing interactions. In this paper, we first put robots' movements into two categories: global—where a robot changes position in the home—or local—where a robot's position does not change, but parts of it move. We also look at the idea of animation and how it can give a robot style. Building on these definitions, we present four movement conditions to classify movement between a human and robot at home. Using familiarity, we can recognize some of these conditions from other interactions we have. Using animation, we can give the robot a style that can make the robot's movement more familiar and easier to understand. We close the paper with possible ways of using this classification system for future research.

Keywords–human-robot interaction; animation; style; movement; familiarity; home

I. INTRODUCTION

The "elderly wave" is an issue that many western countries are examining [1]. The number of people that will be retiring and needing care will be much larger than the people entering the workforce for these jobs. Consequently, some countries and areas have set goals that more elderly should live independently at home longer. One way of addressing this issue is to turn to *welfare technology* that can assist the elderly [2]. One example is using the Internet of Things and smart home sensors for reporting and helping elderly complete tasks [3][4]. Another example is using these sensors to provide someone with a warning when things go wrong, such as an elderly person falling [5]. But all these sensors in the house may transform it from a home to a place where elderly may feel they are under surveillance with no privacy and little control over their life.

Robots may be an alternative for helping out at home. Robots can be mobile and customized for handling different kinds of tasks. A robot may give the person a chance of feeling in control and a feeling of privacy. For example, an elderly person could tell the robot to leave the room. Robots cannot replace a human in every context, but it can provide support for issues when a person cannot be present or help contact a person. Robots may help in ways that would otherwise require another human to always be present, and have diverse knowledge. For example, robots can collect data and use algorithms to give early warnings about issues (e.g., falling down, low blood pressure, or suffering from poor nutrition).

Robots have been making their way into the home. Domestic robots cut the lawn and vacuum, but other robots have been around to provide entertainment (the robot dog Aibo [6]) or stress relief (the Paro seal [7]). We are working to create a robot that stays with the elderly at home and serves as a safety alarm and perform other services that the elderly want. The aim is to improve quality of life of the elderly at home. It is an opportunity for collaboration between the robot, the elderly at home, and the assisted living help.

Unlike other types of technology at home that is either stationary or wearable, robots can move around and possibly perform tasks on their own. This raises several questions: How can we make the robot familiar? How do robots' movement affect our interaction with them? Are there better ways for this movement to happen? We wish to examine these questions. We will begin by trying to define animation, movement, and style (Section II). Next, we propose a framework for classifying movements between a person and a robot (Section III). Then, we will look at how familiarity can help make this robot motion familiar, and we will present how style created through animation can help in this familiarity (Section IV). Finally, we will look at some limitations with this framework and ideas for future work (Section V) before concluding the article (Section VI).

II. BACKGROUND: MOVEMENT, ANIMATION, AND STYLE

First, we will define animation, movement, and style for this paper. We will also look at some projects that have involved robots and animation.

The physical idea of movement (or motion) is a change in position over time that can work for some types of robot movement we will call this *global movement* (Figure 1a). If we were to imagine the robot in a house, global movement would mean the robot moves in a room or moves to another room. Let us define another type of motion where parts of the robot move, but its global position does not change (Figure 1b). This is *local movement*. Returning to our imaginary robot at home above: its local movement would be moving parts on its body (for example, rotating its body or moving an appendage on its body) that do not move the complete robot in the room. There is one situation left: *no movement*. That is, when a robot standing still and not moving any parts of the body. To keep the classification system simple, let us assume that no movement is a special case of local movement. Of course, local movement and global movement can be combined.

There are many ways a robot's movement can be accomplished. The robot can move at a constant speed, it can speed up as it starts out and slow down, or it can back up to get a running start and can abruptly stop when it gets to the destination. We can think of these approaches as *animating* the robot. Normally, we associate *animation* with cartoons and film, where one combines frames together to create movement on screens, but the *American Heritage Dictionary* also defines animation as, "the act, process, or result of imparting life, interest, spirit, motion, or activity" [8].

(a)　　　　　　　　　　　　　　　　　　　　(b)
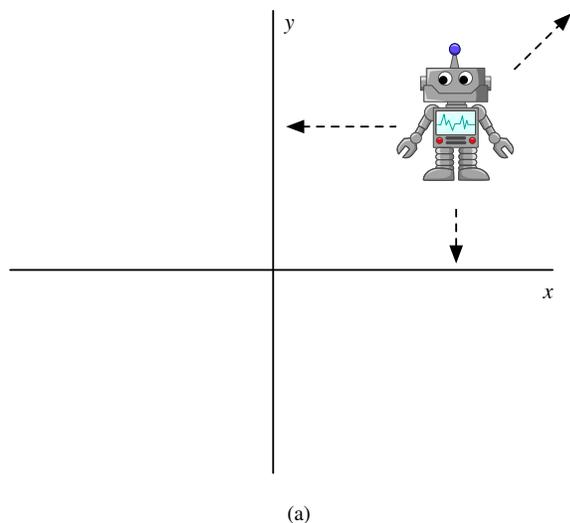
Figure 1. Examples of global and local movement: in global movement (a), the robot moves in a two-dimensional plane; the Aibo laying down and waving (b) is an example of local robot movement.

Another way we can think of animating robots is *moving with style*. With *style*, we are using Gallaher's definition: "the way in which a behavior is performed" [9, p. 133]. Gallaher pointed out that style can also be thought of as *expressive movement*. Gallaher was looking at people's style, but this concept has been successfully applied to robots [10].

How does animation make the robot move with style? Animation gives the robot an interesting way of moving. This animated motion can make the robot seem likes it has a personality. The motion can also help the robot to better communicate what it is planning to do (the robot's intention for lack of a better term).

Are there any design principles or guidelines for adding this style? Looking at the history of animation on film, Thomas and Johnston [11] documented twelve principles of animation that animators at Disney used to create good animations. These principles include: (*a*) *squash and stretch*—an animated object squashes and stretches its form, but never truly loses its recognizable shape; (*b*) *anticipated action*—an object needs to prepare itself before performing an action; (*c*) *follow through and overlapping action*—actions are not done in isolation, characters move seamlessly between them; (*d*) *arcs*—limbs move in arcs, not straight up-down, left-right motions; (*e*) *secondary action*—the object's main action causes other secondary actions to occur at the same time; and (*f*) *exaggeration*—over-emphasizing an action helps people understand a characters feelings.

Adopting principles of animation from film can help in making robots animated. Breazeal [12] references them when working on the Kismet robot. Van Breemen [13] tried to apply these principles in the facial expressions of the iCat [14]. His reason for doing this was to make the robot's behavior more natural and less machine-like. This would make the robot easier to accept and have easier interactions.

As mentioned above, animation can make things "look alive" or give them *animacy*. This may also give us some feelings about them. Several experiments have been run where

a person works with an animated robot for a while, but then is asked to "kill" it by, for example, destroying it with a hammer or turning off its power to erase its memory [15]–[17].

There are several examples of using animation to communicate a robot's intention. Takayama, Dooley, and Ju [18] showed how the animation principles can make it easier for a human to understand and predict what a robot is doing. Gielniak and Thomaz [19] found that creating anticipation for motion (i.e., one of the twelve principles of animation from above) made it easier for people to predict what the robot was going to do. In a later study, Gielniak and Thomaz [20] experimented with exaggerating movement for a robot to tell stories. People that saw the exaggerated movements remembered those parts of the story better. These movements need not be big or elaborate. For example, in a nod to the animation principle of secondary action, a study with elderly people ran by Louie, McColl, and Nejat [21] found that the participants enjoyed the "facial expressions and different tones of voice" [21, p. 148]. Finally, Baraka, Rosenthal, and Veloso [22] made the intentions of a robot moving around independently more understandably by adding animated lights to make the robot's state more visible.

III. Classifying Human and Robot Movement

Human-computer interaction (HCI) has a tradition of studying the use, design, and evaluating ways interfaces and interactions are taking place in different contexts between humans and stationary computers in workplace settings, public places, and home settings. Mobile computing raised the importance of the context of use and interaction to researchers' attention. This lead to the research area of *context aware computing* [23]. Ubiquitous and ambient computing raise the idea of computers in the home, but hidden from view and not moving.

The conditions for the interaction taking place between humans and computers in a stationary and mobile situation are similar; there is a stable spatial arrangement between the people and computers. In both situations, humans and computers are interacting in the same place, with a stationary relationship in-between the human and the computer.

The spatial conditions change when robots enter the scene. We may be used to moving things outside our home like automobiles, buses, boats and trams. We are all living in a shared world where we are used to other people moving around at home and in public places. Yet in a home setting, we are not familiar or used to *things* moving around except when moving into a place, (e.g., renovating, or moving out of a place). Furniture is moved, and there is movement of things by residents and guests in the home, but very few things move *on their own*.

In the home context, we can classify this movement: (*a*) Things that we move around: furniture, peripherals, clothes, machines like vacuum cleaners or furniture on wheels. (*b*) Things moving themselves: domestic robots (robot vacuum cleaners and robot lawn mowers) and our safety alarm robots. If we examine the spatial arrangement for movement between one human and one robot and classify the movement as *local* and *global* from Section II, we get the following four conditions (Table I):

1) Human moves locally and the robot moves locally,
2) Human moves locally and the robot moves globally,
3) Human moves globally and the robot moves locally, and
4) Human moving globally and the robot moving globally.

TABLE I. MOVEMENT CONDITIONS FOR HUMANS AND ROBOTS

Condition	Human	Robot
1	Local	Local
2	Local	Global
3	Global	Local
4	Global	Global

This framework for classification also gives a way to compare the human-robot movement with other objects. In Condition 1 and Condition 3, when the robot is moving locally (including being completely still as per Section II), the human is either moving locally or globally. This is similar to conditions for interacting with stationary computers. We can see Condition 1 when a person watches TV, and we can see Condition 3 when a person approaches a switch or walks towards a remote control.

The other conditions are more unusual in the home before robots. For example, Condition 2 happens when toys are moving. But Condition 4 does not have good analogs other than perhaps chasing a moving toy. These other conditions also indicate something that is unfamiliar. Gibson and Ingold [24] find we are indeed familiar with movement, and they work out the importance of movement on perception. But what we are not used to is being around things that move—and not being controlled or steered by other people! What can we do to make this situation more familiar?

IV. FAMILIARITY AND MOVING ROBOTS AT HOME

To make robots moving at home more familiar, we need to examine what familiarity is. Once we have an idea what familiarity is, we can look at how we can make a robot's movement familiar. We can also see how animation and style can help in making these situations familiar.

A. Familiarity

Familiarity plays a role in how people interact and use things and objects. The common sense meaning of familiarity is trivial. The familiar is often what we are comfortable and safe with, be it situations, technologies, relationships, activities or other people. We are often unfamiliar with is things we do not engage with, have no skills with or understanding of, or are foreign to us.

These three concepts; involvement, understanding and unity of user-world are, according to Turner and Walle [25], ideas that we can apply to get a grip on familiarity. Turner and Walle stated that familiarity unfolds over time. Hence, familiarity points to activities of daily living where we are engaged and skillful people going about our everyday lives. When breakdowns or interruptions happens, i.e., something is faulty, missing or in our way for us to proceed, the separation between people and their world is taking place, and equipment and activities become visible as objects for our analysis [26]. However, this is not the primordial way of being in the world.

Van de Walle, Turner, and Davenport claimed, "What is observable are the outcomes: easiness, confidence, success, performance, which are all manifestations or signs of familiarity," [27, p. 467]. This shows that familiarity is subjective; it can be described by observing activities or asked questions in interviews. One way of investigating possible ways of using robots in the home is to learn from what we already are familiar with of movement. Harrigan and Rosenthal [28] provided an introduction into non-verbal human behavior, including *proxemics*. Hall [29] observed that human-social spatial distances vary by degree of familiarity between the people interacting and the number of people interacting. Hall later provided a framework that identifies the main social spatial zones by interaction and situations. He estimated these distances visually in terms of arms lengths, close contact and threat/flight distances—and researchers have since assigned precise numerical values.

B. Making a robot's movement more familiar

For all people, movement is a phenomenon that they are familiar with. Moving within a place such as a home are examples of the movement that we all experience in our everyday life. We are familiar with seeing other people move. We are familiar with seeing things move (for example, in the house). We move about in concert with things such as phones, watches, and footwear. There is nothing extraordinary with this familiarity of movement of things and other people.

By focusing on familiarity of movement, we build on people's preexisting involvement, understanding and relationship with the everyday world. We know how to move along bicycles, automobiles, trains, trucks, metro cars as large objects that move about. Even though we do not see the driver of a metro car, we are familiar with the movement that unfolds. In our homes, we are familiar with other people, and perhaps animals, moving about the house. We are also familiar with moving things around in our homes by ourselves, or by other people. Moving a chair closer to the fireplace, or carrying wood to the stove are two examples that we are familiar with. If not done by ourselves, it is at least something that we have seen in pictures or on film.

Walters, Dautenhahn, Te Boekhorst, *et al.* [30] have used human-human proxemics for investigating interaction with

robots. Yet this is all based upon a model of distances and proxemics that has human-human movement as its base. Another possibility may be to use human-thing distances and proxemics as the starting point. This would be grounded in our familiarity with movement of things.

If we think of familiar movement where an object moves with us, we can find some examples: (*a*) navigating traffic, with cars, bicycle and public transport material, (*b*) walking with a rolling suitcase, (*c*) operating a wheelchair, (*d*) operating a walking stick, and (*e*) operating a walker. We are all familiar with these movements, but there is no field of literature to find out more about these types of movement. Yet the concept of familiarity helps us find these examples.

C. Making a robot more familiar by giving it style

In Section II, we posited that an animated robot moves with style. Several of the robots from Section II do not move from their location, but the way they move their parts makes them appear more friendly and easier to relate to. Animation also makes it possible to experiment with different kinds of interaction depending on the animation style.

To jump back to HCI and graphical user interfaces, programmers can move items across the screen in many ways, but animating can help people understand what is going on when they are using a program. There is a different mood or tone when a window minimizes by shrinking down to a small area on the screen versus simply scaling the window. Just as animated graphical user interface elements help explain what is going on, the way a robot moves can be helpful in explaining what is going on in an interaction with a robot. Naturally, there are limitations—for example, robots must obey the laws of physics and some types of motion put extra strain on the robot [31]—but we can give a robot its own style by animating it.

Animation can be present in all conditions in Section III. For example, in Condition 1, the robot does not move globally, but its local movement can still be animated by moving parts of its body. This animation can give the robot a style, add some personality, and give the effect of presence for the robot [32]. For example, if the person is asking a question or the robot is providing feedback, animation can provide feedback to the person about the robot's state and other relevant information. This does not have to be complex; a part of the robot rotating can suffice, or lights blinking to indicate the robot is listening. A simple rotation that follows the person can help keep the interaction going in Condition 3.

Condition 2 can build on top of the animation from Condition 1. Here, the animation of parts of the robot's body can be combined with its global movement. For example, if the person asks for some privacy, the robot can start moving away. This can give the person a sense of what the robot is going to do. Animation could also affect how fast the robot moves, combining animations could make a robot "appear" angry, sad, surprised, or happy.

Since these two conditions can build on top of each other, animation can also help with the *transition* between them. This can offer the human a cue to the robot's intention (i.e., it is about to move or about to stop as Gielniak and Thomaz [19] researched). From the robot's side, it can also try to determine the human's cue to get information if it too should start or stop.

Condition 4 is still unfamiliar for most of us in indoor settings. But animating the robot's movements can give it a style to make it seem like this condition is more familiar. The way the robot moves can imitate another person or an animal. These imitations can remind us of other situations where we and something else move, and this can make a robot and human moving at the same time more familiar.

Looking at proxemics, animation can aid in building a rapport between the robot and the human. Mumm and Mutlu [33] discuss how a rapport is necessary for people to be willing to get (physically) close to a robot or answer personal questions. Mumm and Mutlu also point out that until a rapport is established, certain actions that signal a good rapport (like maintaining eye contact) should be avoided. Obaid, Sandoval, Złotowski, *et al.* [34] found different distances for an approaching robot based on the posture of the human (sitting or standing).

A framework for looking at movement gives us a way to animate this movement and give it style. The way these movements are animated may influence how willing someone is to interact with it. As Saerbeck and Bartneck [35] found when looking at how people experienced motion of robots, the speed and way a robot moved caused people to describe the personality or mood of the robot. Building on this work, Noordzij, Schmettow, and Lorijn [36] found people associated negative and positive emotion to a simple robot simply by adjusting how it accelerated. On the other hand, if a robot moves too slow, people may assume that the robot can never get anything done and simply will not interact with it. If we desire interaction with a robot that moves, we need to make it an inviting experience.

Finally, familiarity does not have to just be in the *form* of the robot. A challenge we can find from Hoffman and Ju [37] is that robots that resemble something we are familiar with (e.g., an animal or human) may bring expectations that are difficult to achieve with current technology. Instead, a robot moving expressively can be used for clues to interaction. These movements follow physical properties in the world that people are already familiar with and give them a starting point for their interaction.

V. FUTURE WORK

There are limitations with this classification as it only looks at a specific case of one human and one robot, and we can explore different directions of movement as well. Yet, even at its simple level, it gives us many questions we can investigate: how can the robot move to bring trust and assurance when the person is working with the robot? What activities can a robot do that are not available when a technology is stationary or only handheld? What conditions are necessary so that people and robots can work together? How are these interactions affected by the animation, proximity, automation, control, and delegation? We can also examine the transition between the different classifications.

Moving with style can be helpful. But different people prefer different styles, and some style may work well in some situations than others. Finding styles that are compatible with the robot, the people, and the situation will be a challenge.

Returning to the issue of having a robot at home with the elderly. Another issue to look at is how the animation

can be tested. Many of the animation studies that we cited in Section II were run in lab situations. This works well for testing items in a controlled environment, but robots at home need to work in more chaotic environments. Testing the animations out in a home environment may be necessary to see if the animation is helpful for the elderly.

Though we looked at movement conditions, an issue not examined here is control. From our discussions in gathering requirements from the elderly, people have different opinions about a robot moving at home when they have control of its movement versus it moving on its own. There is also a question about what control means in a home situation with the elderly. In Section I, we highlighted the idea of the elderly asking the robot to leave, but are there points when the robot should stay? Can it easily be called back?

As Chanseau, Lohan, and Aylett [38] found, people who wanted a feeling of control also wanted robots to be more autonomous. The size of the robot and a person's anxiety towards robots also influences proxemics. These issues are important when introducing a robot—especially moving robots—in the home of the elderly. Introducing a robot that can detect falls benefits no one if it moves around the home and becomes an obstacle to stumble over in everyday life. Then, it is a fall *creator* for the elderly instead of a *detector*.

Finally, this classification focused on a single robot and a single person at home. But there are many questions one could explore to expand or apply this in other areas. Are there other situations outside of home where this classification applies as well? What happens when you add more "moving parts" like other people and robots? Does animating a robot work in all situations? What about animating robots that have limited movement? These are all questions to explore in future research.

VI. Conclusion

We have defined animation, movement, familiarity, and style. Using these definitions, we have looked at movement of robots in the home and classified the movement in relation to humans and their movements. We have found parallels with other types of movement in the home and ways that having a robot moving in the home may be unfamiliar to someone. We have also suggested animating the robot will make it move with style. This style can give the robot a personality and make the robot more familiar to people living at home.

We have started our investigation with the elderly by running focus groups and discussing the issues of robots at home and how a robot's appearance and movement affects them. The information and the elderly's opinions have been helpful, and they seem interested in what things robots can do. We will be presenting this in future work and are integrating their feedback into our future activities. We hope our classification of movement and incorporating animation can help in this.

Acknowledgments

References

[1] G. Hagemann. (2015). Babyboom og eldrebølge, [Online]. Available from: http://www.norgeshistorie.no/oljealder-og-overflod/hus-og-hjem/1915-babyboom-og-eldrebolge.html [retrieved: 2018-01-17].

[2] D. C. Søndergård, "Future Challenges and the Role of Welfare Technology," Nordic Center for Welfare and Social Issues, Stockholm, Sweden, 2014.

[3] T. Schulz, K. S. Fuglerud, H. Arfwedson, and M. Busch, "A Case Study for Universal Design in the Internet of Things," in *Universal Design 2014: Three Days of Creativity and Diversity*, H. Caltenco, P.-O. Hedvall, A. Larsson, K. Rassmus-Gröhn, and B. Rydeman, Eds., IOS Press, 2014, pp. 45–54, ISBN: 978-1-61499-403-9.

[4] T. Halbach and T. Schulz, "MobileSage – A Prototype Based Case Study for Delivering Context-Aware, Accessible, and Personalized On-Demand Help Content," *International Journal of Advances in Intelligent Systems*, vol. 7, pp. 267–278, 1 & 2 2014, ISSN: 1942-2679.

[5] S. Kido, T. Miyasaka, T. Tanaka, T. Shimizu, and T. Saga, "Fall detection in toilet rooms using thermal imaging sensors," in *2009 IEEE/SICE International Symposium on System Integration (SII)*, 2009, pp. 83–88. doi: 10.1109/SI.2009.5384550.

[6] T. Makimoto and T. T. Doi, "Chip technologies for Entertainment Robots - present and future," in *Digest. International Electron Devices Meeting,*, 2002, pp. 9–16. doi: 10.1109/IEDM.2002.1175768.

[7] K. Wada, T. Shibata, T. Saito, and K. Tanie, "Psychological and social effects of robot assisted activity to elderly people who stay at a health service facility for the aged," in *2003 IEEE International Conference on Robotics and Automation (Cat. No.03CH37422)*, IEEE, 2003, 3996–4001 vol.3, ISBN: 0-7803-7736-2.

[8] *Animation*, in *American Heritage Dictionary of the English Language*, 5th, Houghton Mifflin Harcourt Publishing Company, 2011.

[9] P. E. Gallaher, "Individual differences in nonverbal behavior: Dimensions of style.," *Journal of personality and social psychology*, vol. 63, no. 1, p. 133, 1992.

[10] J. E. Young, T. Igarashi, E. Sharlin, D. Sakamoto, and J. Allen, "Design and Evaluation Techniques for Authoring Interactive and Stylistic Behaviors," *ACM Trans. Interact. Intell. Syst.*, vol. 3, no. 4, 23:1–23:36, 2014, ISSN: 2160-6455. doi: 10.1145/2499671.

[11] F. Thomas and O. Johnston, *The Illusion of Life: Disney Animation*, 1st Hyperion ed. New York: Hyperion, 1995, 575 pp., ISBN: 978-0-7868-6070-8.

[12] C. Breazeal, *Designing Sociable Robots*, ser. Intelligent Robotics and Autonomous Agents. Boston, Massachusetts, USA.: MIT Press, 2002, ISBN: 978-0-262-02510-2.

[13] A. J. N. van Breemen, "Bringing robots to life: Applying principles of animation to robots," in *Proceedings of Shapping Human-Robot Interaction Workshop Held at CHI 2004*, Citeseer, 2004, pp. 143–144.

[14] A. van Breemen, X. Yan, and B. Meerbeek, "iCat: An Animated User-interface Robot with Personality," in *Proceedings of the Fourth International Joint Conference on Autonomous Agents and Multiagent Systems*, ser. AAMAS '05, New York, NY, USA: ACM, 2005, pp. 143–144, ISBN: 978-1-59593-093-4. doi: 10.1145/1082473.1082823.

[15] C. Bartneck, M. Verbunt, O. Mubin, and A. Al Mahmud, "To Kill a Mockingbird Robot," in *2007 2nd ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 2007, pp. 81–87. doi: 10.1145/1228716.1228728.

[16] C. Bartneck, M. van der Hoek, O. Mubin, and A. Al Mahmud, ""Daisy, daisy, give me your answer do!" switching off a

robot," in *2007 2nd ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 2007, pp. 217–222.

[17] C. Bartneck, T. Kanda, O. Mubin, and A. Al Mahmud, "The perception of animacy and intelligence based on a robot's embodiment," in *2007 7th IEEE-RAS International Conference on Humanoid Robots (Humanoids 07)*, IEEE, 2007, pp. 300–305, ISBN: 978-1-4244-1861-9.

[18] L. Takayama, D. Dooley, and W. Ju, "Expressing Thought: Improving Robot Readability with Animation Principles," in *Proceedings of the 6th International Conference on Human-Robot Interaction*, ser. HRI '11, New York, NY, USA: ACM, 2011, pp. 69–76, ISBN: 978-1-4503-0561-7. doi: 10.1145/1957656.1957674.

[19] M. J. Gielniak and A. L. Thomaz, "Generating anticipation in robot motion," in *2011 RO-MAN*, 2011, pp. 449–454. doi: 10.1109/ROMAN.2011.6005255.

[20] ——, "Enhancing Interaction Through Exaggerated Motion Synthesis," in *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction*, ser. HRI '12, New York, NY, USA: ACM, 2012, pp. 375–382, ISBN: 978-1-4503-1063-5. doi: 10.1145/2157689.2157813.

[21] W.-Y. G. Louie, D. McColl, and G. Nejat, "Acceptance and Attitudes Toward a Human-like Socially Assistive Robot by Older Adults," *Assistive Technology*, vol. 26, no. 3, pp. 140–150, 2014, ISSN: 1040-0435. doi: 10.1080/10400435.2013.869703.

[22] K. Baraka, S. Rosenthal, and M. Veloso, "Enhancing human understanding of a mobile robot's state and actions using expressive lights," in *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 2016, pp. 652–657. doi: 10.1109/ROMAN.2016.7745187.

[23] P. Agre, "Changing places: Contexts of awareness in computing," *Human Computer Interaction*, vol. 16, pp. 177–192, 2-3 2001.

[24] K. R. Gibson and T. Ingold, *Tools, Language and Cognition in Human Evolution*. Cambridge University Press, 1994, 504 pp., ISBN: 978-0-521-48541-8.

[25] P. Turner and G. van de Walle, "Familiarity as a basis for universal design," *Gerontechnology*, vol. 5, no. 3, pp. 150–159, 2006, ISSN: 1569-111X. doi: 10.4017/gt.2006.05.03.004.00.

[26] T. Winograd and F. Flores, *Understanding Computers and Cognition: A New Foundation for Design*. Intellect Books, 1986, 236 pp., ISBN: 978-0-89391-050-1.

[27] G. Van de Walle, P. Turner, and E. Davenport, "A study of familiarity," in *Human-Computer Interaction-INTERACT*, vol. 3, 2003, pp. 463–70.

[28] J. Harrigan and R. Rosenthal, *New Handbook of Methods in Nonverbal Behavior Research*. Oxford University Press, 2008.

[29] E. T. Hall, *The Hidden Dimension*, 1st. New York, NY, US: Doubleday & Co, 1966, vol. xii, 201 pp.

[30] M. L. Walters, K. Dautenhahn, R. Te Boekhorst, *et al.*, "An empirical framework for human-robot proxemics," in *Procs of New Frontiers in Human-Robot Interaction*, Edinburgh, Scotland, 2009.

[31] M. J. Gielniak, C. K. Liu, and A. L. Thomaz, "Secondary action in robot motion," in *19th International Symposium in Robot and Human Interactive Communication*, 2010, pp. 310–315. doi: 10.1109/ROMAN.2010.5598730.

[32] W. A. Bainbridge, J. Hart, E. S. Kim, and B. Scassellati, "The effect of presence on human-robot interaction," in *RO-MAN 2008 - The 17th IEEE International Symposium on Robot and Human Interactive Communication*, 2008, pp. 701–706. doi: 10.1109/ROMAN.2008.4600749.

[33] J. Mumm and B. Mutlu, "Human-robot Proxemics: Physical and Psychological Distancing in Human-robot Interaction," in *Proceedings of the 6th International Conference on Human-Robot Interaction*, ser. HRI '11, New York, NY, USA: ACM, 2011, pp. 331–338, ISBN: 978-1-4503-0561-7. doi: 10.1145/1957656.1957786.

[34] M. Obaid, E. B. Sandoval, J. Złotowski, *et al.*, "Stop! That is close enough. How body postures influence human-robot proximity," in *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 2016, pp. 354–361. doi: 10.1109/ROMAN.2016.7745155.

[35] M. Saerbeck and C. Bartneck, "Perception of Affect Elicited by Robot Motion," in *Proceedings of the 5th ACM/IEEE International Conference on Human-Robot Interaction*, ser. HRI '10, Piscataway, NJ, USA: IEEE Press, 2010, pp. 53–60, ISBN: 978-1-4244-4893-7.

[36] M. L. Noordzij, M. Schmettow, and M. R. Lorijn, "Is an Accelerating Robot Perceived As Energetic or As Gaining in Speed?" In *Proceedings of the 2014 ACM/IEEE International Conference on Human-Robot Interaction*, ser. HRI '14, New York, NY, USA: ACM, 2014, pp. 258–259, ISBN: 978-1-4503-2658-2. doi: 10.1145/2559636.2559793.

[37] G. Hoffman and W. Ju, "Designing Robots With Movement in Mind," *Journal of Human-Robot Interaction*, vol. 3, no. 1, pp. 89–122, 2014, ISSN: 2163-0364. doi: 10.5898/JHRI.3.1.Hoffman.

[38] A. Chanseau, K. S. Lohan, and R. Aylett, "How motor speed of a robot face can influence the "older" user's perception of facial expression?" In *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 2015, pp. 468–473. doi: 10.1109/ROMAN.2015.7333596.