# Designing On-Body 2D Patterns to Enhance Subsidiary Communication for Telepresence Robots

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*Abstract*— **As robotic telepresence is becoming more common and receives academic and industrial attention, the issue of how to increase the expressiveness of the telecommunication is becoming also important. In this paper, we explored the usage of 2D visual patterns displayed on the robot's body as a subsidiary visual channel to enhance communication between two remote users with a robot. Through a series of workshops with seventeen designers, we designed ten user-scenarios and corresponding 2D visual patterns to be used in four different environments: home, office, hospital, and department store. We then presented these patterns on the body of the M4K telepresence robot, and investigate with an online survey the expressiveness of the patterns in each of the proposed environments. Our results show the possibility of complex 2D visual expressions on the body of telepresence robots as a supplementary communication method and introduce a possible strategy for design those. Moreover, our results also show the overall perception and acceptability of these patterns split into three categories (progress indication, attention requests, and emotions) and across different environments.**

## I. Introduction

Nowadays, telepresence robotics is not only a field of mere academic interest but is becoming more popular as robotic products start appearing in public places, including hospitals and stores. This commercial endorsement has raised new interest in research issues about the feasibility of telepresence robots in a variety of environments [8], and about new possible ways to interact and communicate with remote users through telepresence robot. While most of the emphasis is placed on verbal communication, researchers have also highlighted the need to enrich non-verbal communication with subsidiary channels. For example, Scheirer et al. [10] showed that over 80% of communication among humans is encoded in facial expressions and body movements, and non-verbal visual cues are considered essential communication tools during face-to-face communication [3, 7] and during remote communication [14]. However, often these subtle movements and expressions, as well as body language, are difficult to be conveyed through telepresence robots.

Researchers have therefore tried to use alternative communication modalities, such as sound [7, 12, 16] and light [6, 12, 13, 15] as subsidiary non-verbal telecommunication channels that can integrate how users communicate with telepresence robots. Among these, LEDs strip and expressive lights placed around the robot's body have received the greatest attention from researchers [3] because of their technical feasibility and availability at low cost. However, these light displays are often in the shape of 1-dimensional LEDs arrays or low- resolution LEDs matrices, limiting the possible vocabulary for the visual language. Some robots also employ screens in place of body parts to display animations and information (e.g., map of the floor [9]), but these visual information represent primary non-verbal communication channels rather than auxiliary visual channels that operates at the same time with primary channels to foster the expressiveness of the communication with a remote user.

In this paper, we are interested in exploring the design space of complex two-dimensional visual patterns displayed on the robot's body to enhance the subsidiary visual communication channel, and to increase the expressiveness of a conversation with a remote user in various environments. Specifically, we conducted a sequence of workshops where 17 designers created several usage scenarios, and extracted functional and emotional states that could be visually displayed on the robot's body, and finally designed a set of visual patterns for four different environments (home, office, hospital, and department store) using a multitude of shapes, colors and temporal visual patterns. Finally, we tested these visual patterns with 24 participants and found perceptual differences of how they are perceived by the users depending on the surrounding environment. The rest of the paper describes the related work, the results from the design workshops, and the analysis of users' perception of the produced visual patterns.

## II. Related Work

Considerable research was devoted in the past to understand the usage of telepresence robots across different physical environments. Specifically, hospitals, offices and homes have been highlighted as the most promising operational environments for telepresence robots by several researchers [8]. More recently shopping centers have adopted telepresence robots [2], with the objective to reach a larger audience, for both marketing purposes and customers' assistance. Consequently, researchers have studied how to use non-verbal communication to foster more natural subsidiary interaction with people in public spaces [3, 5].

Specifically, several nonverbal communication modalities that facilitate how robots express information and emotions have been widely researched, including sound effects [7, 12, 16], bodily movements [16, 11], and visual stimuli through LED displays [6, 12, 13, 15]. While body movements are mostly appropriate for humanoid or anthropomorphic robots with arms and legs [1, 17], LEDs are more widely applicable to robots with a variety of form factors [6, 13]. For instance, Szafir et al. [13] adopted a strip of LEDs around an autonomous drone to communicate the intended movement

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direction. Y. Kim et al. [6] presented the design of expressive visual patterns using a circular LED strip, while Baraka et al. [3] demonstrated the effectiveness of using a single line of LEDs attached on the body of the telepresence robot as a communication medium. Moreover, some of these visual patterns went through extensive user-studies to validate the feasibility utilizing task-oriented user scenarios, showing promising results.

Based on such related works, we propose the usage of two-dimensional visual patterns displayed on the body of telepresence robots to increase the expressiveness of subsidiary visual channels. Differently from the previous work [3], we focus on rich two-dimensional patterns that could be either displayed on screens placed on robots' bodies, or directly projected on the robots' outer shell. As in the previous work [6], we asked a group of designers to create these visual patterns based on several scenarios situated in different physical environments, and we tested the users' response to these patterns through a multi-variate questionnaire.

## III. DESIGNING THE VISUAL PATTERNS

Seventeen designers (10 female) aged 22-32, (*M*=25.4, *SD*=2.2) and with at least two years of design education specialized in interaction design were recruited for three sequential workshops, which aimed to decide what subsidiary information to express and how to express them on a telepresence robot. The specific goals of the three workshops were to generate usage scenarios (workshop 1, with 8 designers), to extract functional states and emotional states to express through the robot (workshop 2, with 6 designers), and to design visual patterns for each of these (workshop 3, with 5 designers) as described in the Table 1.

In the first two workshops, designers were simply asked to generate realistic telepresence robot usage scenarios considering four different environments – home, hospital, office, department store, and to use these scenarios for determining what kind of subsidiary information would improve the telepresence communication in the form of a video-voice chat. The designers generated 20 different scenarios, and finalized them with paragraphs of text. Using an affinity diagram they then extracted functional and emotional states, and finally selected a set of 10 items to be expressed (see Table 2). We then grouped these 10 items into three main categories: progress indication, attention request, and emotion. The two workshops took approximatively two hours each, and designers were compensated with 20 USD/hour in local currency for their participation.

TABLE I. OVERVIEW OF THREE SEQUENTIAL WORKSHOPS

| | ***Objective*** | ***Participant*** | ***Result*** |
|---|---|---|---|
| Work-shop 1 | Scenario generation | P1 (F/26), P2 (M/26), P3 (M/26), P4 (M/29), P5 (F/25), P6 (F/32), P7 (M/22), P8 (M/25) | Twenty telepresence robot usage scenario (5 for each environment) |
| Work-shop 2 | Eliciting expressions from the scenarios | P9 (F/24), P10 (M/24), P11(M/25),P12 (F/25), F13 (F/24), F14 (F/23) | 10 functional and emotional states to be designed |
| Work-shop 3 | Designing visual patterns | P1 (F/26), P10 (M/24), P15 (F/25), P16 (F/26), P17 (F/24) | 10 visual patterns to convey the 10 expressions |

TABLE II. EXPRESSIONS SELECTED USING AN AFFINITY DIAGRAMMING DURING THE FIRST WORKSHOP

| # | ***Expression name*** | ***Expression group*** |
|---|---|---|
| 1 | Connecting | Progress indication |
| 2 | Moving | |
| 3 | Observing | |
| 4 | Quiescent | |
| 5 | Emergency | Attention request |
| 6 | Eye-catching | |
| 7 | Comforting | Emotion |
| 8 | Curious | |
| 9 | Glad | |
| 10 | Perplex | |

The objective of the last workshop was to generate suitable visual patterns for each of the functional and emotional states derived from the former two workshops. For this workshop, we introduced to the designers the M4K (Mobile 4D+ Communication Kiosk) robot developed at KIST (Korea Institute of Science and Technology) and displayed in Figure 1, to be used as a service platform. M4K is equipped for remote video conferencing, but it is also capable of autonomous operation when the video-conferencing mode is off. It was designed to operate in various environments such as hospitals and stores, both as a telepresence and partially autonomous robotic kiosk.

The designers were asked to create different visual patterns to represent the ten expressions selected through the workshop. The designers were instructed that the patterns were to be displayed on the robot's body (area highlighted in dashed yellow line in Figure 1), but no further restriction was imposed. Each designer individually produced at least one visual pattern per expression (total number of patterns: 60). Then, in the finalization stage, designers were asked to share with each other what they produced and to discuss their reasoning. Finally, all designers together unanimously selected and modified the visual patterns in order to produce a single final pattern per expression. The outputs were represented as sequences of individual drawings, as in Figure 2. As a final workshop output, we took the sequential sketches for each visual pattern and created a corresponding 2D animation using Adobe After Effect. For producing the final video, each animation was mapped on the 3D model of the robot's body, achieving a compositing as the one in Figure 2.

Figure 1. M4K service robot platform technical details.

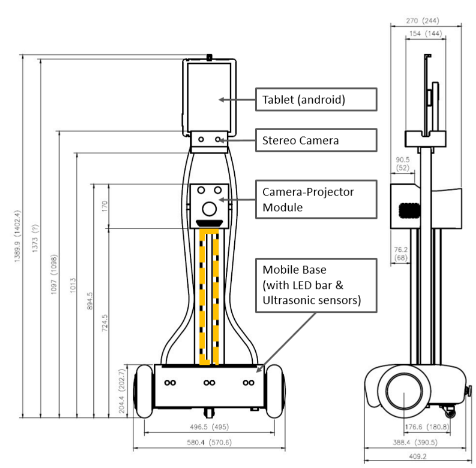


Figure 2. Examples of sequential images on the M4K robots' body; a) Moving; b)Comforting; c)Emergency; d) Quiescent

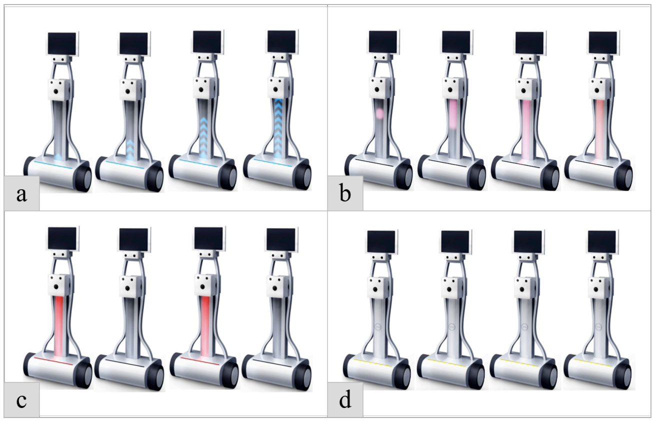


Figure 3. Animations of the M4K robot placed in each environment; a) Department store; b) Home; c) Hospital; d) Office.

While there was no guideline provided, the designers mainly adopted three main strategies to create the visual patterns that convey the different emotion qualities: changes in color, icons, and motions. Most patterns used two or more combinations of these elements. For example, several patterns used bottom-up directional motions of visual elements across the robot's body (Figure 2.a), but the appearance of these elements varied according to the specific expression. Hence, designers chose green dots moving bottom-up for the expression meaning a connection in progress with a teleoperator, blue arrows to signal the robot's intention to move, a red horizontal line to communicate that the teleoperator is remotely connected and the robot's camera is recording, and questions marks to suggest that the robots need more information.

Other patterns used zooming effects, rotations and blinking. For example, some designers used a directional motion with a pink circle increasing size so to occupy the entire robot's body, and gradually changing to red. Such animation meant to convey a warm feeling and a cozy atmosphere (Figure 2.b). Another directional motion utilized rotating blue icons displayed in the center of the robot's body indicating a disorder. Blinking patterns were mostly used to communicate salient information, such as emergency situations or the robot's emotional state with a high degree of arousal. Specifically, a red blinking pattern occupied the full body signaled an emergency state (Figure 2.c), while a sequence of multiple colors or strips of colors (e.g., a rainbow) represented respectively the "eye-catching" and the "glad" states. Finally, the "quiescent" state was represented without the use of any motion, but only a static icon displayed in the middle of the body (Figure 2.d).

## IV. User Perception Evaluation

We conducted an online survey to understand how different environments influenced the user perception for various visual patterns displayed on the body of a telepresence robot. The patterns considered were those generated in the design workshop described above. We recruited 24 participants (7 females) through an anonymous online call, aged 20 to 40 (*M*=26.5, *SD*=4.37). Only three of the participants reported having had an experience using telepresence robots (in a department store, a laboratory, or a conference). Participants took approximately 40 minutes to complete the survey and were compensated with 15 USD in local currency.

The survey consisted of 40 survey pages presented to the participants in random order, where each of the ten visual patterns generated during the workshop was tested in four different environments (home, hospital, office and department store). Similar to the previous work [17], each page contained a video representing the visual patterns displayed on the robots' body while the robot was placed in one of the four environments in our study. Under the video, a block of text described a specific usage scenario with more details considering the visual expression, the situation, and the surrounding environment. For example, in the case of the 'observing' expression used in the hospital environment, the scenario read like this:

*You are a patient in an intensive care unit (ICU). Your family is looking after you and is remotely inspecting the treatment you receive using the robot, while remaining outside the restricted area accessible only by the staff.*

As in the previous work [13], there were five questions to clarify the usability of the visual pattern design underneath the scenario in a seven-point Likert scale. The participants were asked about their level of agreement for the following five statements: 1) I can understand the intent of the robot; 2) I have confidence in interpreting the robot intentions; 3) The communication is intuitive; 4) The communication is clear; 5) The robot is perceived as a collaborator.

## V. Results

Results were analyzed with a repeated measure two-way analysis of variance (ANOVA). Greenhous-Geisser correction was used where Mauchly's test of sphericity was significant ($p < 0.05$). Considering that the Cronbach's alpha coefficient for all the five questions was very high (above 0.95), as in the previous work [13], we performed a statistical analysis only for the mean scores of these perception questions, instead of looking at individual scores. We report the main effect for the expression types, $F(5.67, 675.00) = 83.00$, $p < 0.001$, $\eta_p^2 = 0.42$. A detailed overview of the mean score of the four environments for each expression is presented on the left of Figure 4. The overall average score was 4.73 ($SD$ = 2.84), with 'emergency' scoring the highest ($M$ = 5.92, $SD$ = 1.95)

Figure 4. User perception scores of the 10 expressions across the environment, color-mapped according to the groups.

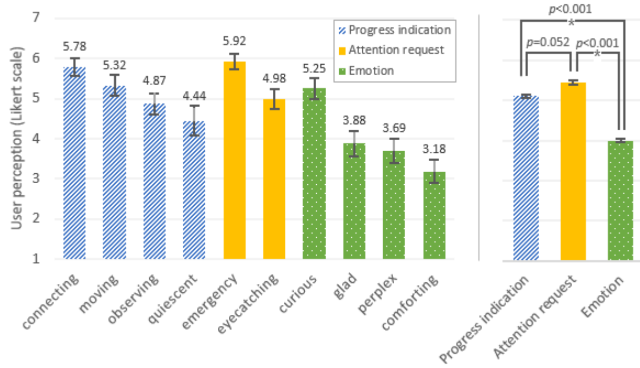
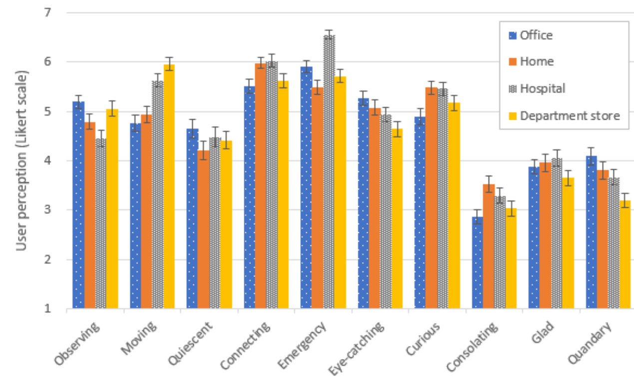



Figure 5. User perception scores of the ten expressons in each environment




and 'comforting' scoring the lowest ($M$ = 3.18, $SD$ = 2.93). One-way analysis of variance to elucidate difference according to the group of expressions - progress indication, attention request, and emotion - yielded significant difference, $F(2, 957) = 67.13$, $p < 0.001$, $\eta_p^2 = 0.12$ as presented on the right side of Figure 4.

Post-hoc comparison using the Bonferroni test indicates that the average user perception score of progress indication group ($M$ = 5.10, $SD$ = 1.64) and attention request group ($M$ = 5.45, $SD$ = 1.37) are significantly different from that of the emotion group ($M$ = 4.00, $SD$ = 1.74), $p < 0.001$. The score of progress indication and of attention request did not yield significant differences ($p$ = 0.052).

We also report the main effect for environment, $F(3, 357) = 7.55$, $p < 0.001$, $\eta_p^2 = 0.06$. A post-hoc pairwise comparison with Bonferroni correction reveals significant differences between the office and the hospital ($p < 0.02$), and the department store and the hospital ($p < 0.001$). Also the interaction effect between environment and expression type was found significant $F(15.72, 1879.07) = 11.15$, $p < 0.001$, $\eta_p^2 = 0.81$. Interestingly, when comparing the overall perceptions of the patterns, the hospital environment scored the highest ($M$ = 4.85, $SD$ = 1.51), followed by the department store ($M$ = 4.64, $SD$ = 1.51), the office ($M$ = 4.70, $SD$ = 1.68), and the home ($M$ = 4.73, $SD$ = 1.63). Means scores for each expression and for each environment are plotted in Figure 5.

## VI. Discussion

In this paper, we presented the process to generate ten 2D visual patterns mapped to ten expressions and grouped in three categories (progress indication, attention request, emotions) that are used to enhance non-verbal communication with a telepresence robot, through a series of workshops with designers. In a study with users, we investigated the perception level of visual patterns, and how well users perceived them reflecting the intended message. Through this study, we also identified the impact that different surrounding environments (e.g., contexts) had on the users' perception of the different visual patterns. Our results reveal three main findings.

First of all, as highlighted in Table 3, it is clear that designers used a variety of method to generate the 2D patterns regardless of the expression categories. In other words, it does not appear that designers opted for specific design strategies depending on which category the expression belongs to, but rather explored similarly various techniques across categories, ranging from the use of multiple colors, motions of visual elements, or icons. However, it seems that the most effective expressions were those that used a single color, icons and simple motions regarding a qualitative analysis of our result

TABLE III. Expressions Classification According to the Visual Starategies

| Expression group | Expression | Motion of Visual Elements | | | Color | | Icon | | Perception score(1-7) |
|---|---|---|---|---|---|---|---|---|---|
| | | *Directional* | *Non-directional* | *Static* | *1* | *2 or more* | *used* | *not used* | |
| **Progress indication** | **Connecting** | X | | | X | | X | | 5.78 |
| | **Moving** | X | | | X | | X | | 5.32 |
| | **Observing** | X | | | X | | | X | 4.87 |
| | **Quiescent** | | | X | X | | X | | 4.44 |
| **Attention request** | **Emergency** | | X | | X | | | X | 5.91 |
| | **Eye-catching** | | X | | | X | | X | 4.98 |
| **Emotion** | **Curious** | X | | | X | | X | | 5.25 |
| | **Glad** | | X | | | X | | X | 3.88 |
| | **Perplex** | | | X | X | | X | | 3.69 |
| | **Comforting** | X | | | | X | | X | 3.18 |

(see Table 3). On the other side, expressions that were less effectively communicated used more than one color, no motions (static), and no icons. Although further work will have to ascertain the validity of these interpretations by analyzing a larger set of visual patterns, we are inclined to believe that users' preferred and better-understood patterns which used no more than two combinations of elements among colors, icons, and motions.

Perhaps a more interesting finding is that expressions across categories were perceived very differently, with the *emotion* category scoring the lowest. While all the patterns for progress indication and attention request received a score higher than the average (>4), all patterns representing emotions except one (curiosity) failed to convince the users (see Table 3). Interestingly, designers extensively borrowed the visual language from the user interfaces of consumer appliances for visual patterns in the categories of notifications and request of attention. However, they lacked the consistency of a visual language when creating the patterns for emotions "comforting", "glad", and "perplex". For example, users easily agreed that a red blinking pattern would express a state of "emergency", or that moving green dots would mean "connecting" as it happens for smart-phone graphical interfaces. They also could easily interpret the "questions marks" in the "curious" emotional state, but they felt at lost at interpreting a rainbow pattern as the "glad" state. From these findings we can easily conclude that the users' perception and understanding of the 2D patterns was not a function of the visual strategies used in the design (e.g., number of colors, type of motions, icons vs. no icons), but rather about how the visual language was coherently represented. Visual patterns that reflected commonly available graphical interfaces were interpreted much more easily than patterns which left room for subjective interpretations.

The last finding is about the effects of the environment on the interpretation and perception of the visual patterns. In general, the same patterns were interpreted differently depending on the environment (i.e., the context) in which the robot was situated. Specifically, overall the hospital performed best, and the department store performed the least. While we do not have enough data to conclude with absolute certainty the reasons for this result, we speculate that amount of external distractions/stimuli could be one possible reason for these variations. For example, in a department store a user interacting with a robot could be distracted by the surrounding environment and other customers, while in a hospital the level of attention toward a robot would be much higher (e.g., in order to seek more information about a patient). Future work will aim to investigate this issue in depth.

Overall, we can identify clear strategies for producing understandable and compelling visual patterns for non-verbal communication (colors, icons and simple animations) from our findings. We also note that a clear and shared visual language is essential for improving the communication between the robots and its observer. Finally, we report how the environment may affect the interpretation of the visual patterns displayed on the robot's body.

## VII. Conclusions and Future Work

In this paper, we attempted to design and validate two-dimensional visual patterns to support non-verbal subsidiary communication in four telepresence robot usage environments. The results of our user study with 24 participants to clarify the user perception of the visual patterns designed show the potential of our expression designs. While we attempted to minimize the limitation of in-lab study by allocating the robot in four different environments and providing scenario and background sounds, in the future it would worth performing another experiment *in the wild* to better ascertain the results with actual users and a real telepresence robot. We also acknowledge that the main limitation of our settings is that participants were asked to give an agreement score to visual patterns that were already associated to specific meanings. Future works will focus on better characterizing whether this mapping can be understood without any prior information given to the users. Moreover, future work will also aim to test projected partitions compared with more traditional visualization methods, such as LED strips and matrices. In addition, conducting more extensive study regarding the number of expressions and environments will better clarify the relationship between the visual factors of the emotion patterns and their recognition rate, as well as the interaction effect between environment and expressions: such characterization goes beyond the scope of the current work Finally, future research will also attempt to validate these results with robots of different shapes and form-factors, and attempt to derive concrete design guidelines for designing 2D patterns displayed on the robot's body.

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## References

[1] R. Andreasson, B. Alenljung, E. Billing and R. Lowe, "Affective Touch in Human–Robot Interaction: Conveying Emotion to the Nao Robot", International Journal of Social Robotics, 2017.

[2] Awabot, "The Beam telepresence robot for 2.0 customer service", Awabot, 2018. [Online]. Available: http://awabot.com/en/applications-en/telepresence-and-customer-relationship. [Accessed: 05- Apr- 2018].

[3] K. Baraka and M. Veloso, "Mobile Service Robot State Revealing Through Expressive Lights: Formalism, Design, and Evaluation", International Journal of Social Robotics, vol. 10, no. 1, pp. 65-92, 2017.

[4] C. Bethel and R. Murphy, "Survey of Non-facial/Non-verbal Affective Expressions for Appearance-Constrained Robots", IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), vol. 38, no. 1, pp. 83-92, 2008.

[5] E. Kim, S. Kwak and Y. Kwak, "Can robotic emotional expressions induce a human to empathize with a robot?", RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication, 2009.

[6] Y. Kim and T. Fong, "Signaling Robot State with Light Attributes", Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction - HRI '17, 2017.

[7] T. Komatsu, "Toward Making Humans Empathize with Artificial Agents by Means of Subtle Expressions", Affective Computing and Intelligent Interaction, pp. 458-465, 2005.

[8] A. Kristoffersson, S. Coradeschi and A. Loutfi, "A Review of Mobile Robotic Telepresence", Advances in Human-Computer Interaction, vol. 2013, pp. 1-17, 2013.

[9] LG Newsroom, "LG AIRPORT ROBOTS TAKE OVER KOREA'S LARGEST AIRPORT | LG Newsroom", 2018. [Online]. Available: http://www.lgnewsroom.com/2017/07/lg-airport-robots-take-over-koreas-largest-airport/. [Accessed: 05- Apr- 2018].

[10] J. Scheirer and R. Picard, Affective Objects. Mit Media Laboratory Perceptual Computing Section Technical Report, 524, 2000,

[11] D. Sirkin and W. Ju, "Consistency in physical and on-screen action improves perceptions of telepresence robots," *2012 7th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, Boston, MA, 2012, pp. 57-64.

[12] S. Song and S. Yamada, "Expressing Emotions through Color, Sound, and Vibration with an Appearance-Constrained Social Robot", Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction - HRI '17, 2017.

[13] D. Szafir, B. Mutlu and T. Fong, "Communicating Directionality in Flying Robots", Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction - HRI '15, 2015.

[14] K. Tanaka, H. Nakanishi, and H. Ishiguro, “Physical Embodiment Can Produce Robot Operator's Pseudo Presence”, Frontiers in ICT, vol.2, 2015

[15] K. Tsui, A. Norton, D. Brooks, E. McCann, M. Medvedev and H. Yanco, "Design and development of two generations of semi-autonomous social telepresence robots", 2013 IEEE Conference on Technologies for Practical Robot Applications (TePRA), 2013.

[16] K. Winkle and P. Bremner, "Investigating the real world impact of emotion portrayal through robot voice and motion", 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), 2017.

[17] M. Zecca et al., "Whole body emotion expressions for KOBIAN humanoid robot — preliminary experiments with different Emotional patterns," RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication, Toyama, 2009, pp. 381-386.