Effect of Height in Telepresence Robots on the Users' Spatial Awareness

Oliver Gawron(✉), Lisa Keller, Karsten Huffstadt, and Nicholas H. Müller

University of Applied Sciences Würzburg-Schweinfurt, Sanderheinrichsleitenweg 20, 97074 Würzburg, Germany
mail@olivergawron.com

Abstract. Since reduction of personal contact is key in fighting the COVID-19 pandemic, remote communication solutions saw a rise in importance. Next to the more common forms like video and audio conference calls, telepresence solutions are also becoming more popular. Telepresence robots can be remotely driven and allow, with the help of cameras and displays on the robot and the users' side, face-to-face communication with onsite personal, establishing a remote telepresence. Depending on the model, the height of the robot can be adjusted by the remote user. Even though the effect of the height in relation to onsite people is being researched, the effect on the users' side has not been examined immensely. Therefore, this work examines the effect of the difference in height between a telepresence robot and its user on the users' spatial awareness. Subjects have experienced the usage of a telepresence robot driving at a fixed height through a video. Afterwards, they filled out a questionnaire, which asks the user to answer questions about the experience. These questions were regarding the spatial awareness of the user in the remote location, asking them to estimate different parts of the tour. Their estimations were mapped to the users' height, allowing to correlate the difference in height and the users' spatial awareness. The work has shown, that only the perceived height of the telepresence robot was affected by the difference in size. However, more tests have to be conducted, to factor in multiple robot heights.

Keywords: Telepresence robots · Remote communication · Spatial awareness

1 Introduction and Background

Since reduction of personal contact is key in fighting the COVID-19 pandemic, remote communication solutions saw a rise in importance, with downloads of video conferencing apps in march 2020 being magnitudes higher than in the fourth quarter of 2019 [1]. Next to the more common forms like video and audio conference calls, telepresence solutions are also becoming more popular. Telepresence Robots are in general movable platforms with cameras, speakers, a microphone and a display. A remote user can log into the robot to control it, while

P. Zaphiris and A. Ioannou (Eds.): HCII 2021, LNCS 12785, pp. 268–277, 2021.
https://doi.org/10.1007/978-3-030-77943-6_17

experiencing the onsite surroundings on a computer screen. Simultaneously, the users' face is being projected live onto the robots screen, allowing onsite personal to communicate with the user in a face-to-face manner, establishing a remote telepresence.

This form of telepresence allows to be implemented in a wide variety of fields. In teaching oriented environments like schools and universities, telepresence robots can be deployed to be used by lecturers and students attending classes [2,3]. Students using the robots in educational tasks have shown to embrace teamwork more and improve in conflict management and coordination [4]. Additionally, students motivations has shown to be positively improved when using robots [5–7]. Groups of people can solve challenges through multiple robots which has shown to have a positive team building effect [8]. Furthermore, the private sector has shown an increased interest in telepresence robots being used in personal homes [9].

Some models of telepresence robots allow the user to change the robots height e.g. with a telescopic pole. This could theoretically allow the user to set the robots size to match his or her own height. But not all telepresence robots feature a changeable height or are limited to ranges that cannot perfectly represent all humans. Additionally, the functionality might be hidden in the user interface or come with a drawback, like a reduced speed at greater heights, which even though available, does not encourage the user to change the height or even knowingly change it to be smaller than himself or herself. This leads to many telepresence users not having the telepresence robot adjusted to their seize and thus experiencing the world on a different height than they are used to.

2 Research Question and Hypotheses

The effect of the height of telepresence robots has been subject of many studies before. A study has showed that its size does not effect a remote instructors' authority and a shorter than life-size robot was perceived friendlier the instructors' students [10]. Furthermore, when used by persons in leadership roles, a study has shown that locals found the robot user less persuasive when the robot was smaller than himself [11]. But what effect a difference in height between the user and the driven robot has, had not been investigated immensely. To establish an immersive telepresence on the user side, the user should experience the same spatial awareness, as he would being onsite. Therefore, this work investigates the following question:

RQ1: Does the difference in height of a telepresence robot effect the users' spatial awareness?

Since spatial awareness is a complex construct, that cannot be measured by a single data point, Elito's and Czarnolewski's "Everyday Spatial Behavioral Questionnaire" was used to split the research question in three measurable hypotheses [12]:

H1: The difference in height between a telepresence robot and its user does affect the users estimation of sizes seen through the telepresence robot.
H2: The difference in height between a telepresence robot and its user does affect the users estimation of the telepresence robots driven distance.
H3: The difference in height between a telepresence robot and its user does affect the users estimation of the height of the telepresence robot.

3 Approach

Because the usage of telepresence robots varies heavily from user to user, a uniform experience could not be achieved by performing the test on actual telepresence robots. To generate a homogeneous experience the participants can be exposed to, a video of the usage of a telepresence robot was used in the study. It shows the web interface of the used telepresence robot, featuring mainly the robot's view of its surroundings. To allow the participants to view the video, it was uploaded to the popular video platform YouTube.

The used telepresence robot was a Double 2 from Double Robotics. It features a telescopic pole allowing the camera to be lifted from 119 cm up to 157 cm high. This maximum was also the height used for the experiment, as it is closer to the average human height, allowing the differences to the users heights to be proportionate greater. The size of the telepresence robot did not change during the video. Figure 1 shows a screenshot of the uploaded video.

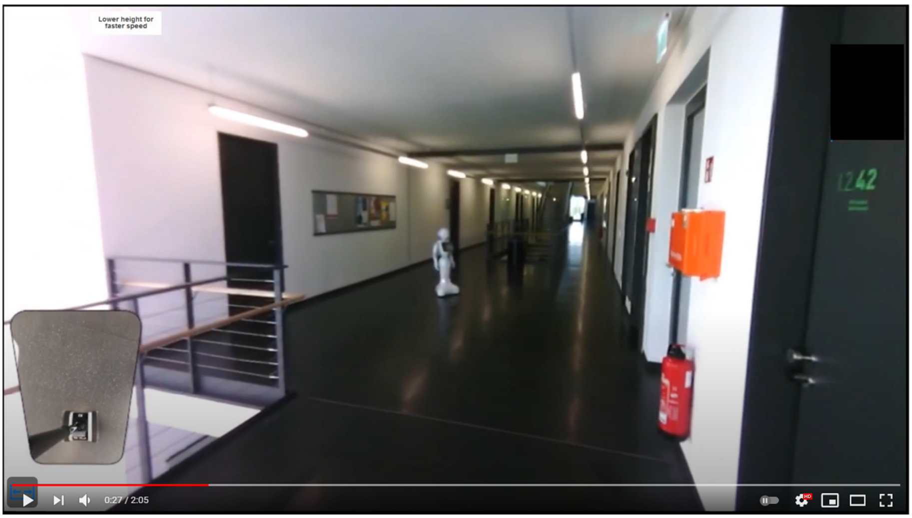

Fig. 1. Recorded video uploaded to YouTube. The Pepper robot is visible in the distance. Link to the video: https://youtu.be/a3NxMjaAxbE

In order to have the participants estimating a driven distance, the telepresence robot drove during the video through a room and a hallway, totalling a distance of 27.7 m. As mentioned in Sect. 1, the higher the robot, the slower its speed. Since the telepresence robot drove at maximum height it was rather slow and took 2 min and 5 s for this distance. During this commute, fairly common objects like doors, chairs, fire extinguishers and a one liter Coca Cola bottle were placed, to allow the user to get a sense of the scale of the environment.

The estimation of sizes was also a main subject of this work. To not have the participants estimate a size previously known to them, a rather uncommon item was needed for them to guess. The 121 cm high Pepper humanoid robot from Softbank Robotics fits this specification and was placed on the route. Participants can see the robot early on in the video, 20 s after it started, as the telepresence robot approaches it until it stops in front of it. Afterwards, at second 50, the telepresence robot turns and continues its route, with the Pepper robot out of sight for the rest of the video. This allowed the participants to see the Pepper robot for 30 s uninterrupted from different distances, creating a baseline to consider their estimation about its size.

Next to the estimation of a completely unknown size, the estimation of a relative common object was prepared. Since an adult human man is probably seen by every participant on a daily basis, one was part of the video for its height to be estimated. With 178 cm the person was about average for a German adult man [13]. The person is visible between minute 1:34 and 1:50. In these 16 s, the participant can see him from different angles and distances, allowing the participant to estimate his size in questionnaire afterwards. Figure 2 shows the person in the video.

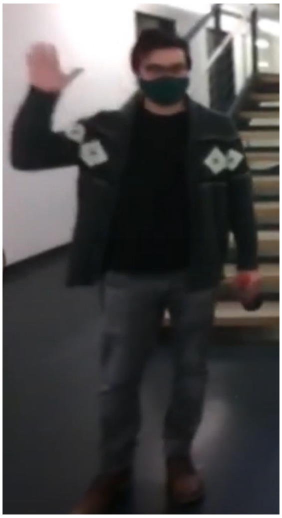

Fig. 2. Cropped video frame containing the person.

The participants were asked to watch the video once and then immediately fill out the questionnaire seen in Sect. 4.

4 Methods

In order to examine the research questions and hypotheses (refer to Sect. 2), a quantitative questionnaire was designed which participants filled out at the end of the experiment. The designed questionnaire (listed below) is based on the findings of Elitos's and Czarnolewski's "Everyday Spatial Behavioral Questionnaire", which concluded, that estimating the size of a previously seen object or estimation a distance are valid data points to measure someone's spatial awareness [12]. In addition to the questionnaire, information about the participants' age, gender and, most importantly, their size were collected.

1. Estimate the total driven distance of the telepresence robot.
2. Estimate, how tall the white robot in the video was.
3. Estimate, how tall the person in the Video was.
4. Estimate, how tall the driven telepresence robot was.

5 Results and Analysis

Participants ($N = 39$) were aged 19 to 51. Moreover, 21 (53.8%) were male, 17 (43.6%) female, and 1 (2.55%) did not specify their sex. The average participant was male, 25.85 years old ($\sigma = 6.4$) and 174,13 cm ($\sigma = 8.4$) tall.

Since every hypothesis is based on the difference in height between a telepresence robot and its user, each data point needed an additional. This value was called ΔParticipantSize and was calculated by subtracting the participants' height with the height of the telepresence robot. This concluded, that the average participant was 17,13 cm ($\sigma = 8.4$) taller than the telepresence robot. Every participant was 0 cm to 31 cm taller than the telepresence robot.

Additionally, the estimations of the size of the Pepper robot, the size of the human, the driven distance and the height of the telepresence robot also got compared to the actual measured values, creating four new Δ-values. Since all data points are metric, Pearson correlations were used to determine relationships between the values. The used significance level was $p \leq 0.05$.

Estimation of Sizes

The null hypothesis of H1 states, that the difference in height between a telepresence robot and its user does not affect the users estimation of sizes seen through the telepresence robot. To prove this, there cannot be a statistical significant correlation between ΔParticipantSize and ΔPepperRobot or a statistical significant correlation between ΔParticipantSize and ΔPerson.

The participants average guess of the height of the Pepper robot was only 7 mm smaller than the actual robot ($\sigma = 25,7$ cm) with ΔPepperRobot ranging from -71 cm to $+39$ cm. The participants average guess of the height of the person was 1,1 cm smaller than the actual person ($\sigma = 4$ cm) with ΔPerson ranging from -8 cm to $+4$ cm. This smaller standard deviation was expected, as humans have a general knowledge on how tall other humans are.

There is no significant correlation between the variable ΔPepperRobot and the variable ΔParticipantSize with r = 0.061 p = 0.714. The corresponding graph can be seen in Fig. 3.

There is a small, positive correlation between the variable ΔPerson and the variable ΔParticipantSize with r = 0.181 p = 0.27. The corresponding graph can be seen in Fig. 4.

As both p-values are above the significance level, the null hypothesis of H1 cannot be rejected.

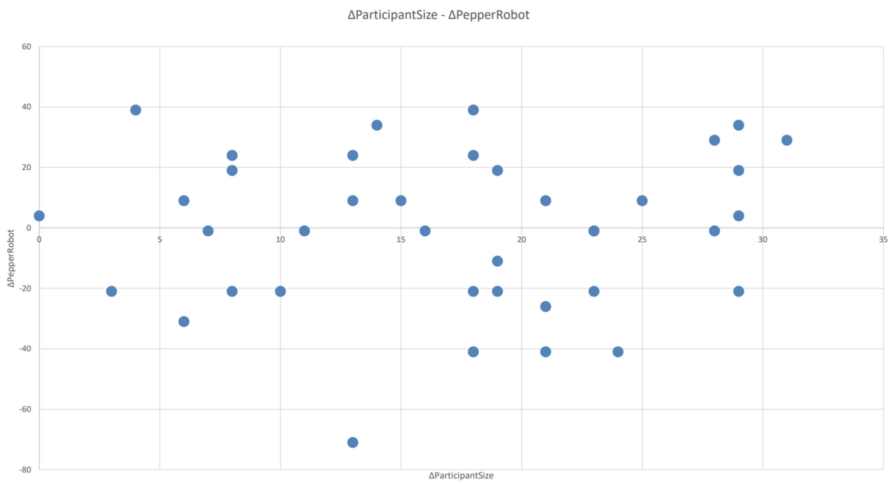

Fig. 3. ΔPepperRobot and ΔParticipantSize, r = 0.061, p = 0.714

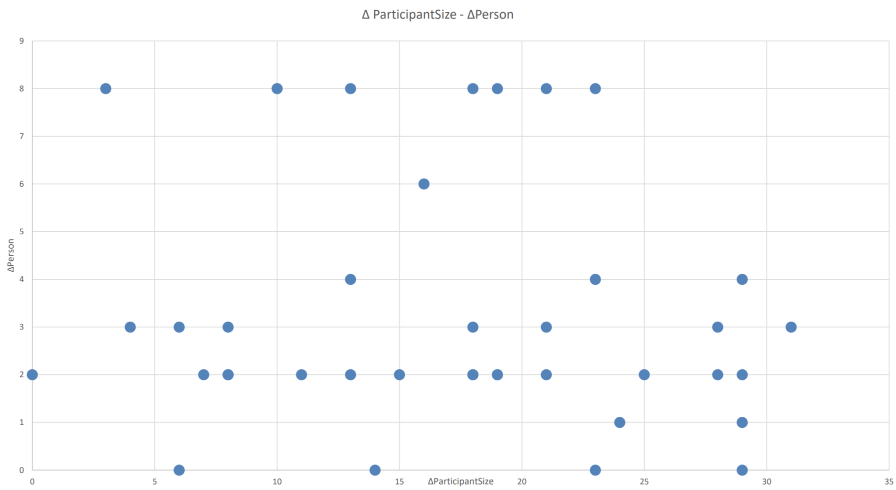

Fig. 4. ΔPerson and ΔParticipantSize, r = 0.181, p = 0.27

Estimation of Driven Distance

The null hypothesis of H2 states, that the difference in height between a telepresence robot and its user does not affect the users estimation of the telepresence robots driven distance. To prove this, there cannot be a statistical significant correlation between ΔParticipantSize and ΔDistance.

The participants average guess of the driven distance of the telepresence robot was 15 m over the measured distance ($\sigma = 43$ m) with ΔDistance ranging from -22 m to $+172$ m.

There is no significant correlation between the variable ΔDistance and the variable ΔParticipantSize with $r = -0.039$ $p = 0.816$. Therefore, the null hypothesis of H2 cannot be rejected. The corresponding graph can be seen in Fig. 5.

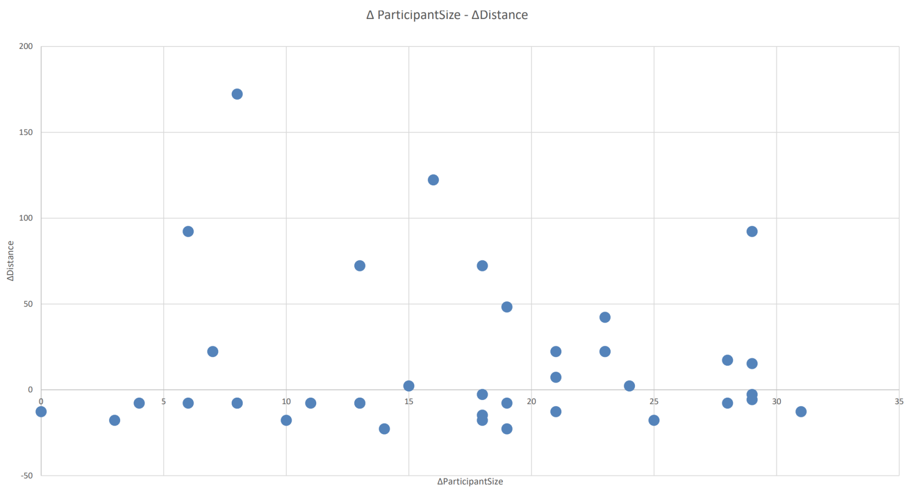

Fig. 5. ΔDistance and ΔParticipantSize, $r = -0.039$, $p = 0.816$

Estimation of the Height of the Telepresence Robot

The null hypothesis of H3 states, that the difference in height between a telepresence robot and its user does not affect the users estimation of the height of the telepresence robot. To prove this, there cannot be a statistical significant correlation between ΔParticipantSize and ΔTeleRobotHeight.

The participants average guess of the height of the telepresence robot was -3.7 cm under the measured distance ($\sigma = 24$ cm) with ΔTeleRobotHeight ranging from -57 cm to $+43$ cm.

A Pearson correlation was performed to test whether there was a relationship between ΔTeleRobotHeight and ΔParticipantSize. The results of the Pearson correlation showed that there was a significant positive relationship between

ΔTeleRobotHeight and ΔParticipantSize, r = 0.408, $p \leq 0.01$. Therefore, the null hypothesis of H3 is rejected.

Figure 6 shows the data in addition to a regression line. This regression line intercepts the x-axis at x = 20, meaning that participants who are 20 cm taller than the telepresence robot, are on average more likely to guess the right telepresence robot height.

6 Threats to Validity

As the experiment was conducted with only one fixed height of the telepresence robot, the results are limited to this specific height. Repeating the experiment with a different height could lead to different results. Due to technical limitations, the video quality was substandard. This could have influenced participants' estimations. Also, the dimensions to be estimated could be known independently from the experiment, as participants could be familiar with the Pepper robot and the person in the video. Additionally, participants could be familiar with the location the video was shot, allowing them to estimate the driven distance not only by means of the video. All participants were larger or the same height than the used telepresence robot. Also, conducting the experiment with humans smaller than the used telepresence robot could lead to different results. The participants' age was mainly between 20 and 30 years. Having the participants more distributed between all age groups could have lead to different results.

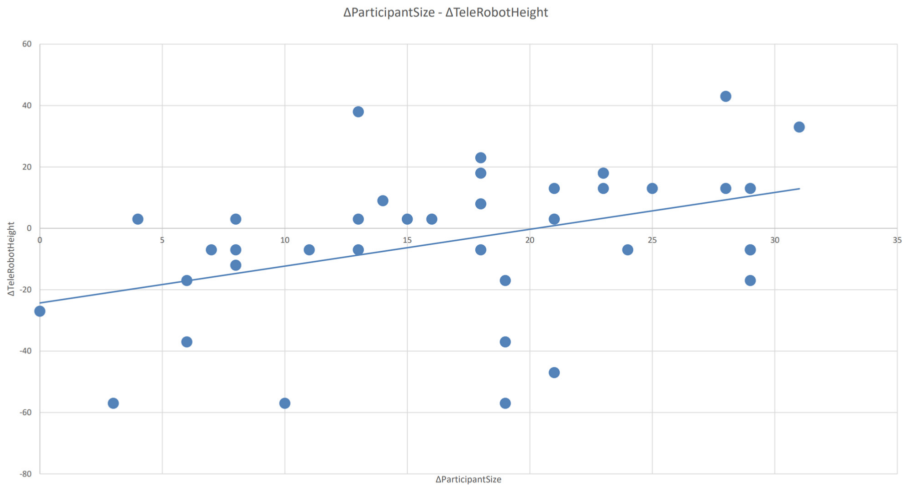

Fig. 6. ΔTeleRobotHeight and ΔParticipantSize with regression line, r = 0.408, p = 0.01

7 Conclusion and Outlook

The results of this study show, that the difference in size between a telepresence robot and its user does have an effect on parts of the users' spatial awareness. It seems to only affect the perceived height of the telepresence robot, but not external factors like object sizes and distances. This means, that in situations, where the users' perception of external sizes is key, the robots height is not a concern and can be adjusted to fit other needs, such as an increased movement speed at smaller heights. On the other hand, in situations, where the users' perceived height is more of a concern, the telepresence robots height should be adjusted accordingly to the users' size to have the spatial awareness least affected. The tests concluded, that this height might be 20 cm below the participants' size, but as discussed in Sect. 6, this might be only true for the in the experiment used height. This is why this topic needs more research regarding spatial awareness at different robot heights. If those confirm our findings and create a conclusive result, it could create an incentive to telepresence robot manufacturers to empathize on the height of their product, either by asking users their size beforehand and adjust, or by simply mentioning the effects of the height difference to its users.

References

1. Perez, S.: Videoconferencing apps saw a record 62 m downloads during one week in march (2020). https://techcrunch.com/2020/03/30/video-conferencing-apps-saw-a-record-62m-downloads-during-one-week-in-march
2. Weibel, M., et al.: Back to school with telepresence robot technology: a qualitative pilot study about how telepresence robots help school-aged children and adolescents with cancer to remain socially and academically connected with their school classes during treatment. Nurs. Open **7**(4), 988–997 (2020). https://doi.org/10.1002/nop2.471
3. Edwards, A., Edwards, C., Spence, P.R., Harris, C., Gambino, A.: Robots in the classroom: Differences in students' perceptions of credibility and learning between "teacher as robot" and "robot as teacher." Comput. Hum. Behav. **65**, 627–634 (2016). https://doi.org/10.1016/j.chb.2016.06.005
4. Scott, M.J., Parker, A., McDonald, B., Lewis, G., Powley, E.J.: Nurturing collaboration in an undergraduate computing course with robot-themed team training and team building. In: Proceedings of the 3rd Conference on Computing Education Practice - CEP 2019, pp. 1–4. ACM Press (2019). https://doi.org/10.1145/3294016.3294019
5. Keller, L., John, I.: How can computer science faculties increase the proportion of women in computer science by using robots? In: 2019 IEEE Global Engineering Education Conference (EDUCON), pp. 206–210 (April 2019). https://doi.org/10.1109/EDUCON.2019.8725212
6. Keller, L., John, I.: Motivating female students for computer science by means of robot workshops. Int. J. Eng. Pedagogy (iJEP) **10**(1), 94–108 (2020). https://doi.org/10.3991/ijep.v10i1.11661

7. Ortiz, O.O., Franco, J.P., Garau, P.M.A., Martín, R.H.: Innovative mobile robot method: improving the learning of programming languages in engineering degrees. IEEE Trans. Educ. **60**(2), 143–148 (2017). https://doi.org/10.1109/TE.2016.2608779
8. Keller, L., Gawron, O., Rahi, T., Ulsamer, P., Müller, N.H.: Driving success: virtual team building through telepresence robots. In: Zaphiris, P., Ioannou, A. (eds.) Learning and Collaboration Technologies. Human and Technology Ecosystems - 8th International Conference, LCT 2021, Held as Part of the 23nd HCI International Conference, HCII 2021, Washington DC, USA, 24–29 July 2021. Lecture Notes in Computer Science, Springer (2021, accepted)
9. Winterstein, K., Keller, L., Huffstadt, K., Müller, N.H.: Acceptance of social and telepresence robot assistance in German households. In: Zaphiris, P., Ioannou, A. (eds.) Learning and Collaboration Technologies. Human and Technology Ecosystems - 8th International Conference, LCT 2021, Held as Part of the 23nd HCI International Conference, HCII 2021, Washington DC, USA, 24–29 July 2021. Lecture Notes in Computer Science, Springer (2021, accepted))
10. Bae, I., Han, J.: Does height affect the strictness of robot assisted teacher? In: Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction, pp. 73–74. HRI 2017. Association for Computing Machinery, New York (2017). https://doi.org/10.1145/3029798.3038401
11. Rae, I., Takayama, L., Mutlu, B.: The influence of height in robot-mediated communication. In: 2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI), pp. 1–8 (2013). https://doi.org/10.1109/HRI.2013.6483495
12. Eliot, J., Czarnolewski, M.Y.: Development of an everyday spatial behavioral questionnaire. J. Gener. Psychol. **134**(3), 361–381 (2007). https://doi.org/10.3200/GENP.134.3.361-381. pMID: 17824404
13. Mensink, G., Schienkiewitz, A., Haftenberger, M., Lampert, T., Ziese, T., Scheidt-Nave, C.: Übergewicht und adipositas in deutschland. In: Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, vol. 56. Robert Koch-Institut, Epidemiologie und Gesundheitsberichterstattung (2013). https://doi.org/10.1007/s00103-012-1656-3