Impact of First Person Avatar Representation in Assembly Simulations on Perceived Presence and Acceptance

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Abstract: This article reports the impact of three different avatar representations on perceived presence and acceptance during an assembly task. The conducted experiment focuses not on the perceived virtual body ownership, but on the limited visibility of the virtual body during a task at a workbench – meaning the view on hands and forearms. The initial question is, if a detailed avatar, which is time-consuming to develop, is needed during a virtual assembly task or if the impact on presence and acceptance caused by the kind of avatar visualisation is negligible. Therefore, three different kinds of avatar representations were used to examine the influence of the avatar on the perceived presence and acceptance. The results of the experiment show that there are no significant differences between the three kinds of avatar representations. All three avatars reach high values for presence and acceptance. Therefore, a partial-body representation is sufficient to obtain a high presence and acceptance level in scenarios which focus on manual tasks on or above a work bench.

1 INTRODUCTION

The advantages in the area of virtual reality (VR) extend the field of potential applications, also for the field of mechanical engineering. Thus, and due to the benefits of virtual environments – like resource saving, non-destructive testing of machine failures and better safety aspects for the user, VR scenarios become a popular tool for training and education. To ensure the transferability of the virtually learned skills to the real tasks, it is necessary to simulate the task as realistic as possible and to reach a high level of presence in these environments. Presence is described as the *"sense of being in the virtual environment*" and is seen as a cognitive state that results from information processing of stimuli in the environment from various senses (Slater and Wilbur, 1997). The sense of presence is affected by several factors and many studies devoted on evaluate the degree of influence these factors exert on it. Schuemie et al. (2001) listed the results of several researchers in this field. Weiss et al. (2006) divided factors, which influence the sensations of presence into three categories: Characteristics of the user, the VR system and the VR task (see Figure 1).

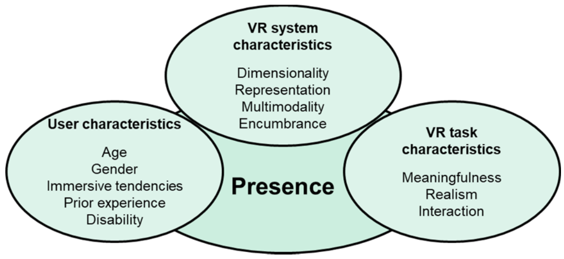

Figure 1: Factors that influence the sensation of presence in the virtual environment by Weiss et al. (2006).

The VR system characteristics also include the way in which the user is represented within the virtual environment (Nash et al., 2000). These representations are called avatars and are the users embodied interface in VR. Such Avatars convey the feeling of direct interaction with the virtual environments and are the direct extension of the user

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in VR (Waltemate et al., 2018). The design of the artificial body affects the so-called "sense of embodiment" and Kilteni et al. (2012) *defines the sense of embodiment (SoE) toward a body B as the sense that emerges when B's properties are processed as if they were the properties of one's own biological body.* Embodiment can be achieved at different levels, which were described by Kilteni et al. (2012) and effect the level of presence (Jung and Hughes, 2016; Slater and Steed, 2000; Tanaka et al., 2015). To reach a strong effect of presence it is necessary to respect the influence of a virtual body on user's perception. Because training and education scenarios in VR focus on processes and tasks, the aspect of the sense of embodiment is mostly unconsidered. This also stems from the fact that the creation of a virtual avatar leads to more effort during the creation of the VR scenarios and that the view on the virtual body during assembly or maintenance tasks is mostly limited to the hands and the arms of the user. Nevertheless, to accomplish a high level of presence, a virtual body should be implemented in training and education scenarios as well. The question is: how detailed and anatomically realistic should this body look and behave in order to reach a high value of presence while keeping the modelling effort as low as possible.

This paper presents a study that compared different avatars in a virtual assembly task to evaluate the influence of the representation towards perceived presence and acceptance of the scenarios.

2 RELATED WORK

Multiple studies on the topic of presence have shown that presence is greatly affected by general embodiment (Jung and Hughes, 2016; Slater and Steed, 2000; Tanaka et al., 2015) and general immersion (Slater, 1999). Moreover, using a self-avatar in immersive virtual reality environments can positively influence the perceived sense of presence and help with perceptual judgements and interaction tasks in these virtual worlds (Slater et al., 1995).

Even the user's ability to perform purely cognitive tasks can be improved by providing tracked self-avatars, as it has been shown that their existence in a scene appears to reduce cognitive load of the user during certain tasks (Steed et al., 2016).

It is noteworthy that such virtual self-avatars have been shown to have a bigger impact on presence during tasks resembling the real world – like locomotion – than while using non-realistic interaction methods, like flying through the virtual world (Slater et al., 1995).

The majority of studies regarding presence and virtual embodiment has been performed outside of the first person perspective, using virtual mirror scenarios (Waltemate et al., 2018), mannequins (Petkova and Ehrsson, 2008) or out-of-body experiences (Lenggenhager et al., 2007), often to overcome the problem of poor visibility of the avatar representation (Waltemate et al., 2018). This stands in contrast to the findings of subsequent studies, that show that using a first person perspective is "*essential for experiencing the sense of ownership over the virtual body*" (Maselli and Slater, 2013) and to the idea that the increased immersion of a head mounted display (HMD) compared to a CAVE system increases both virtual embodiment and agency, as well as presence itself (Waltemate et al., 2018).

There are several top down factors affecting the conceptual interpretation of the virtual body parts the users sees and controls (Waltemate et al., 2018). One of the most important aspects of creating a strong sense of ownership over the virtual limbs is the synchrony between visual and proprioceptive information perceived by the user of the VR system (Sanchez-Vives et al., 2010). This effect is so strong that some research showed that colocation alone could create a basic illusion of embodiment even without full-body motion tracking (Maselli and Slater, 2013).

Further research has shown, though, that motion fidelity plays a vital role in strengthening the believability of self-avatars, even stronger than visual fidelity (Lok et al., 2003). This also is reflected in studies regarding avatars representing other people in the user's virtual environment, where even cartoonish looking animated avatars showed benefits over non animated avatars consisting of basic shapes (Gerhard et al., 2001) or that an avatar consisting of only tracked hands and heads was rated better in terms of copresence and behavioural interdependence compared to a full body avatar with predefined animations (Heidicker et al., 2017). It has been noted that not being able to represent the user's movements, due to miscalibration or other factors, might lead to a break in perceived presence (Slater and Steed, 2000) as it has been shown that violating anatomical constraints – like limbs shown in impossible postures – breaks the full body ownership illusion (Ehrsson et al., 2004; Tsakiris and Haggard, 2005). This has been thought as one of the reasons commercially available software for current home-user HMD-Systems usually don't include a full self-avatar and only present virtual hands or even just the objects in the users hands (Steed et al., 2016).

Argelaguet et al. (2016) showed in a study consisting of hazardous looking virtual objects that had to be avoided during certain simpler tasks, like picking and placing objects or placing your virtual hands in a certain spot, that simplified virtual hands can show benefits as well. For example, they lead to faster and more accurate interactions as well to a greater sense of agency than realistic hands with realistic arms which itself provided the most sense of ownership compared to the simpler representations – at least until a certain degree of familiarisation with the virtual environment has occurred. Blockage of vision when using the more realistic self-avatar and tracking issues where stated as the most probable reasons for these findings (Argelaguet et al., 2016). The issue of the uncanny valley effect (Mori et al., 2012) is also hypothesized as one reason for a finding by Lugrin et al. (2015a) that virtual body ownership decreased slightly when comparing higher human resemblance to robot or cartoon-like avatars.

3 EXPERIMENTAL METHOD

As described in the related work section, previous work compared the influence of avatar representations on different factors affecting the sensation of presence. But the question remains how much avatar representations are contributing to these factors, when the VR scenarios used are not focused primarily on experiencing the virtual avatar alone, but more on the view participants have during tasks related to training scenarios in the field of mechanical engineering. Therefore, we decided to compare three different avatar representations to answer the research question, if different avatar representations vary in the presence and acceptance scores in VR scenarios focussed on manual tasks at workstation tables (meaning primarily seeing the hand and parts of the arms of the virtual avatar).

3.1 Participants

34 participants (22 female and 12 male) with a mean age of 24.38 (SD=3.61) completed the experiment. All participants were students or employees of the university and obtained a financial compensation for their participation. All participants had normal or corrected-to-normal vision. 11 participants reported no prior experience with VR, 13 participants had experienced VR 1 or 2 times and 10 participants had contact with VR 3 or more times before. The total time of the test was 40 minutes while the Participants spent a total of 18 minutes within the virtual environment. The order of the representation of the different avatars was randomized. All participants participated in the study voluntarily and were allowed to abort the experiment at any time.

3.2 Virtual Reality Setup and Avatars

The experiment took place in a room measuring 4.10 x 4.35 meters with a tracking space of 16 square meters approximately. The participants wore an HTC Vive HMD which also used a "Lighthouse" tracking system version 1 to track the participant's position. To study the influence of the avatar representations, three different forms of avatars were developed. The first consists only of two floating human hands, terminating at the wrist (hereinafter called "hands_only"). These follow the movements of the Vive controllers according to their tracking data. Button inputs are visualized by animations displaying gripping or pointing motions of the hands.

The other two avatars consist of different full-body manikins, visible in Figure 2.

Figure 2: Full-body manikins – on the left the lowpoly version and on the right the highpoly version.

Both are anatomically correct and rigged to a human-inspired animation skeleton to allow realistic movements. They diverge in their visual design: One shows very flat shading with little detail in textures (hereinafter called "full_body_lowpoly") the other is designed more realistically with highly detailed skin and cloth fabric (hereinafter called "full_body_highpoly"). Both male and female versions of the models were provided.

Beside the aforementioned hand animations, the full body avatars feature an inverse kinematics system enabling runtime animation of the whole body based on the transformations of the tracked VR hardware. Using the Unity plugin Final IK, targets for the transformations of the body's end effectors, meaning hands, feet and the head, can be set forcing appropriate movements of the untracked body parts. Head tracking was established by accessing the transformation of the HMD itself. Likewise, the hands were tracked using the Vive controllers and the feet by standalone Vive trackers fixed to the user's actual feet by Velcro straps. All different local coordinate systems of the hardware were aligned with the user through different offsets in both position and rotation.

To study the influence of the avatar representation during assembly tasks, we focused on the representation of the hands and arms during the task. The participants were not explicitly instructed to take a closer look at the full body of the avatar but could do so at any time. Figure 3 to 5 show the three views of the participants on the avatar during the tasks.

In the experiment, the participants had to assembly a toy truck using equipment on two workstations that where placed in a workshop-style basement area. One workstation was an assembly table with a height-adjustable table top and swivel arms. The second workstation was a table with a drill press mounted to it. Both workstations were equipped with a virtual monitor on which the assembly steps were explained.

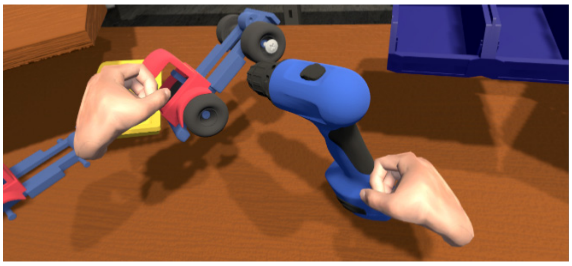

Figure 3: Participants view on the "hands_only" avatar during the assembly task.

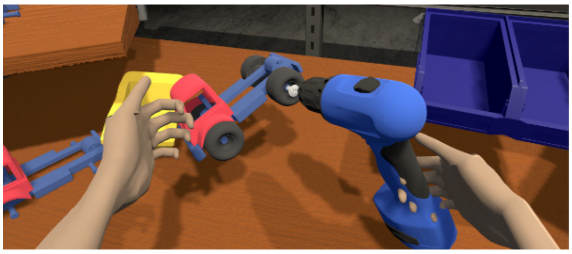

Figure 4: Participants view on the "full_body_lowpoly" avatar during the assembly task.

For each kind of avatar representation, the participants had to fulfil the same tasks: at first, they had to grab a car chassis and a wheel out of the containers in the swivel arms, then they had to move to the drill press to drill a hole in the wheel: After they

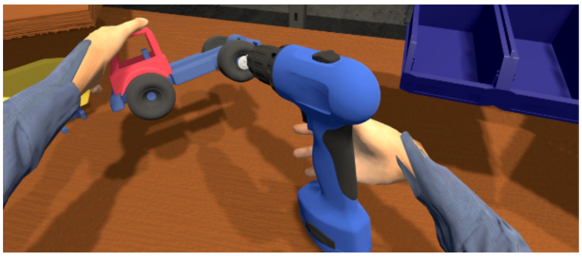

Figure 5: Participants view on the "full_body_highpoly" avatar during the assembly task.

had put the wheel under the drilling press, they switched on the machine and moved the feed lever to the drill position. This procedure was repeated for all four wheels. Afterwards, the participants pre-assembled the wheels to the chassis by snapping them on the axles and moved back to the assembly table. Here they grabbed four screws out of the small load carriers and put them on the right position on the wheels. Then they took the screwdriver and screwed all four screws into the axles, securing the wheels. The last steps was to clip the truck bed on the chassis.

For moving in the virtual room, the participants used real walking in the tracking space.

3.3 Methods

A within-subject study with the kind of avatar representation as independent variable was conducted. The study started with the participation information and the data protection declaration as well a short general questionnaire about previous experience in VR. Afterwards, the instructor shortly explained the Vive trackers and put them on the participant's feet. Before starting the test scenario, the participants completed a quick tutorial, which showed them how to move in the virtual environment and how to pick things up. Then they started the assembly task with the avatar representation in a randomized order. After finishing the assembly task with one avatar, they took off the HMD and filled out the questionnaires. Then they fulfilled the assembly task with the second avatar representation and repeated this procedure. During the task, the participants read the instructions for the assembly on two virtual screens behind the tables, displaying the necessary information regarding the order of the assembly steps. All participants completed the tasks for all three avatar representations successfully. The completion time was not a main focus of the study.

To answer the research question, the presence and acceptance factors were evaluated with post-test questionnaires. The perceived presence was assessed with a shortened version of the ITC-SOPI (Lessister et al., 2001), which included only 12 instead of 44 items and was ranked on a five-point Likert scale. The ITC-SOPI contains four factors, which were measured by the three top loading items per scale.

Sense of physical space: indicates "*a sense of physical placement in the mediated environment, and interaction with and control over parts of the mediated environment*" (Lessister et al., 2001).

Engagement: includes the "*user's involvement and interest in the content of the displayed environment, and their general enjoyment of the media experience*" (Lessister et al., 2001).

Ecological validity: evinces the believability and the realism of the content as well as the naturalness of the environment (Lessister et al., 2001).

Negative effects: summarizes "*adverse physiological reactions*" (Mania and Chalmers, 2004) e.g. motion sickness, dizziness of virtual environments.

For the assessment of the acceptance of the avatar representation, we used the acceptance scale of Van Der Laan et al. (1997). This scale contains nine Likert items, which refer to the two dimensions usefulness and satisfaction.

Based on previous work described in Section 2, we defined the following hypotheses:

H1: A part body avatar reaches better presence values for the factors sense of physical space, ecological validity and negative effects: Previous studies show that simplified virtual hands lead to a better controllability (Argelaguet et al., 2016) and it is also evaluated that failures in the representation of the user's movements lead to reduced sense of presence and embodiment (Ehrsson et al., 2004; Slater and Steed, 2000; Tsakiris and Haggard, 2005). It is suspected that the "hands_only" avatar reaches significantly higher ecological validity values than the more error-prone full body manikins. Additionally, occasionally occurring incapabilities of the full body avatars to perfectly represent the user's movements due to tracking and animation constraints could lead to additional negative effects, because the failures in the representations of the limbs could be experienced as unpleasant.

H2: A part body avatar reaches higher acceptance values due to the possible uncanny valley effect (Mori et al., 2012) and the findings by Lugrin et al. (2015a) that supposedly a less realistic avatar is more acceptable.

H3: A higher fidelity full body manikin reaches a higher ecological validity than a full body representation with lesser details in shading, geometry and textures.

4 RESULTS

To evaluate the influence of different avatar representations during an assembly task, we compared the results of the presence factors of the ITC-SOPI between the different representations. Figure 6 shows the bar charts of the means and standard deviations of the presence factors for all three kinds of avatars.

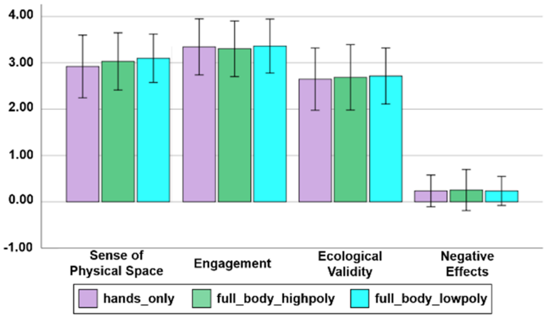

Figure 6: Bar charts of the means of the presence factors for the three avatar representations.

In Table 1 the means and standard deviations of the presence factors are shown. A Shapiro-Wilk test showed that the presence factors are not normally distributed. Therefore, we analysed the data with a Friedman test for paired samples at the 5% significance level. The results are also presented in Table 1. There are no significance effects of the kind of avatar representation on the ITC-SOPI-scores.

Table 1: Means, (standard deviations) and p-values of the ITC-SOPI factors for the three avatar representations.

ITC-SOPI factors		Means	p
Sense of Physical Space	hands_only	3.92 (SD=.68)	.214
	full_body_highpoly	4.03 (SD=.62)	
	full_body_lowpoly	4.09 (SD=.52)	
Engagement	hands_only	4.34 (SD=.61)	.669
	full_body_highpoly	4.30 (SD=.60)	
	full_body_lowpoly	4.36 (SD=.58)	
Ecological Validity	hands_only	3.65 (SD=.67)	.745
	full_body_highpoly	3.68 (SD=.70)	
	full_body_lowpoly	3.71 (SD=.60)	
Negative Effects	hands_only	.23 (SD=.34)	.944
	full_body_highpoly	.25 (SD=.44)	
	full_body_lowpoly	.23 (SD=.31)	

To test if there were significant differences between respectively two kinds of avatar representations in the ITC-SOPI factors, we conducted a Wilcoxon signed-rank test for paired samples at the 5% significance level. No significance differences between the kinds of avatar presentations on the ITC-SOPI factors were found. The results of the significance test are shown in Table 2.

Table 2: Results of the Wilcoxon signed-rank test for the ITC-SOPI factors.

ITC-SOPI factors		p
Sense of Physical Space	hands_only & full_body_highpoly	.149
	hands_only & full_body_lowpoly	.091
	full_body_highpoly & full_body_lowpoly	.729
Engagement	hands_only & full_body_highpoly	.611
	hands_only & full_body_lowpoly	.965
	full_body_highpoly & full_body_lowpoly	.713
Ecological Validity	hands_only & full_body_highpoly	.771
	hands_only & full_body_lowpoly	.668
	full_body_highpoly & full_body_lowpoly	.637
Negative Effects	hands_only & full_body_highpoly	.771
	hands_only & full_body_lowpoly	.894
	full_body_highpoly & full_body_lowpoly	.958

For the evaluation of the acceptance of the avatar representations, we also calculated the means and standard deviations (see Figure 7 and Table 3).

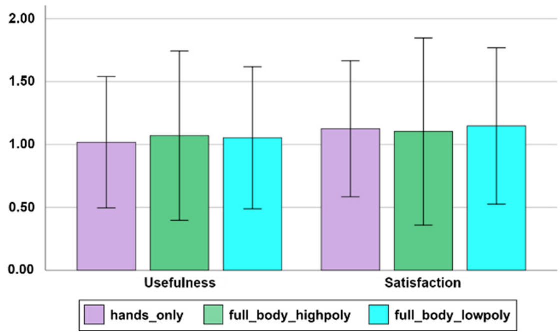

Figure 7: Bar charts of the means of the acceptance scale factors for the three avatar representations.

A Shapiro-Wilk test indicates, that the assumption of normality had been violated. Thus, a Friedman test for paired samples at the 5% significance level was calculated (see Table 3).

There was no significance effect of the avatar presentation on the acceptance scale detected.

A Wilcoxon signed-rank test for paired samples at the 5% significance level was conducted to check for significant differences between two kinds of avatar representation on the acceptance scale, but result in no significant differences (see Table 4).

Table 3: Means, (standard deviations) and p-values of the acceptance scale factors for the three avatar representations.

Acceptance factors		Means	p
Satisfaction	hands_only	1.12 (SD=.54)	.921
	full_body_highpoly	1.10 (SD=.74)	
	full_body_lowpoly	1.14 (SD=.62)	
Usefulness	hands_only	1.01 (SD=.52)	.420
	full_body_highpoly	1.07 (SD=.67)	
	full_body_lowpoly	1.05 (SD=.56)	

Table 4: Results of the Wilcoxon signed-rank test for the acceptance scale.

Acceptance factors		p
Satisfaction	hands_only & full_body_highpoly	.718
	hands_only & full_body_lowpoly	.976
	full_body_highpoly & full_body_lowpoly	.644
Usefulness	hands_only & full_body_highpoly	.235
	hands_only & full_body_lowpoly	.563
	full_body_highpoly & full_body_lowpoly	.526

5 DISCUSSION

Overall, all three avatars reached high values for presence and a good acceptance score. The results for the factor “Sense of Physical Space” obtain a very high score for all avatars, which indicates that the participants had the feeling of being placed in the virtual room and that they felt positively about the available interactions and the controllability of the task. Additionally, the feature of real walking supports the feeling of being placed. The ranking of the “Engagement” factor reached very high values, which strengthens the assessment that the participants enjoyed the tasks and the way they could interact with and within the virtual world. These findings were supported by the feedback the participants gave to the instructor.

The results of the significance tests revealed no significant differences between the avatar representation on the scores of ITC-SOPI and the acceptance scale. Therefore, H1, H2 and H3 have to be rejected. The explanation of these findings refers to several factors: First, all the representations of the avatars showed too much similarities, especially in the visualisation and animation of the hands, so that the perceived differences where too small to be mirrored by the questionnaires.

The second factor is that the participants had little to no contact with VR-scenarios before, making it possible that this lack of experience could bias their assessment of the visualisations due to the small sample size they could compare it to. The low experience levels regarding VR could also affect the enjoyment of the virtual task, considering the novelty character of the sensation of exploring virtual Environments (Brade et al., 2017). This is strengthened by the exceedingly positive feedback the participants gave to the instructor. More experienced users could be expected to display a more critical view on the presented avatars, but the sample set of the study did not allow such an evaluation.

The third and most important factor is, that the participants noticed no significant differences in the avatar representations for they were primarily focused on the tasks and had a limited view on the parts of the avatars, besides from the hands itself. Even though the focus of the study was deliberately laid on such a first person view during a table-based assembly task for exactly these reasons, the differences between the floating hands and the full body avatars were expected greater. As the attention of the participants lied mainly on the hands and not on the other body parts, for all tasks consisted mainly of manual tasks, the findings of this study should be verified for other actions, like climbing stairs or sitting down on chairs, for example.

These factors are corroborated by the findings of Lugrin et al. (2015b): They showed that there are no significant difference between non-realistic and realistic self-avatars, though limited to the representation of the users arm, when the tasks that need to be fulfilled draw the users attention away from mainly beholding the avatar. This is in contrast with situations where the user beholds the avatar not only from the first person view but also in a virtual mirror. Then "realistic avatars also evoked a significantly higher acceptance of the virtual body to be one's own body concerning the illusion of virtual body ownership" which was shown by Latoschik et al. (2017) Therefore, it can be expected that the time the user has time to actively behold the avatar is an influencing factor for presence and acceptance.

Particular because there are no significant differences measured, the outcome of the study lessens the effort needed to create VR based training and education scenarios, because it indicates, that there is no necessity for a highly detailed avatar to strengthen the perceived presence and acceptance during such scenarios containing mainly manual assembly task. Therefore, difficult and time-consuming creation processes regarding anatomically correctly modelled and tracking-based animated avatars can be reduced to focus on the body parts directly needed to fulfil the given training tasks.

6 CONCLUSIONS

The current study evaluated the effect of different avatars on perceived presence and acceptance during a manual assembly task. The results show that the tested avatars did not differ significantly concerning presence and acceptance measures. Both full body manikins reached high presence and acceptance values as well as the "floating hands" avatar. Therefore, it can be concluded that, if the focus of the simulated task lies on manual activities during which the view on the avatar is mainly limited to the hands and arms, no full body manikin is necessary.

Because the conducted study considered mainly manual, table-based assembly activities, the transferability of the results on other task is limited. To proof the findings on other tasks, a second study should address assembly and maintenance task which involve different postures, like crouching, climbing, or in general involve more body-related activities.

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