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# The LEDs move pilot study: the Light Curtain and physical activity and well-being among people with visual and intellectual disabilities

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## Abstract

*Background* Moving around and being physically active can often be challenging for people with a visual impairment. The combination of a visual and intellectual disability can make being physically active even more difficult. The aim of the current study was to examine whether a technological device for physical activity promotion would be associated with more movement and whether using it would be experienced as enjoyable for people with visual and intellectual disabilities.
*Methods* A randomised multiple baseline design was used for this study. The participants were nine adults with a visual impairment and an IQ between 20 and 50. As participants interacted with the Light Curtain, movement was measured with triaxial accelerometers embedded in the Empatica E4 wristband. Independent observers scored activity, alertness and well-being from video-recordings using the following observation lists: the Happiness Feature Score (HFS) and the Arousal and Valence Scale (AVS).
*Results* Physical activity measured with the accelerometer and positive excitement measured with the AVS significantly increased among participants when they were engaged with the Light Curtain compared with care-as-usual activities. Well-being measured with the HFS did not show a significant difference between the baseline and intervention phases.
*Conclusions* Engagement with the Light Curtain increased physical activity and positive excitement in persons with visual and intellectual disabilities, but more research is necessary to understand how the Light Curtain might affect happiness and well-being.

**Keywords** intellectual disability, light curtain, physical activity, technology, visual impairment, well-being

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## Background

Low levels of physical activity increase risk for health problems such as obesity and cardiovascular disease (Cavill *et al*. 2006; de Rezende *et al*. 2014). Rates of sedentary behaviour are high among people with intellectual disability (ID) (Dairo *et al*. 2016; Hsieh *et al*. 2017), who are disproportionally overweight and obese, in part because of insufficient engagement in physical activity (Rimmer and Marques 2012; Hilgenkamp *et al.* 2012b; Hsieh *et al.* 2014). Thus, they are at risk for a range of health problems. Because limitations in decision-making and cognitive functions (Bramston and Mioche 2001) can lead to difficulties coping with activity-induced stress, people with ID need additional support during such exercises (Temple 2007; Bodde and Seo 2009). In addition, performing physical activity could evoke stress for people with ID, for example, because of the requirement to follow rules during sports participation or a perception of the activity as boring (Hutzler and Korsensky 2010). For these reasons, although promoting physical activity among people with ID is crucial, the activity itself must meet their needs. In this study, we examined whether a technological device for physical activity promotion, the Light Curtain, could contribute to increased physical activity along with enjoyment of the activity.

Among the population of people with ID, the proportion with visual impairments is higher than among the typically developed population (Evenhuis *et al.* 2001). The prevalence of visual impairments and blindness of 13.8% and 5.0% in the ID population are much higher than the 1.4% and 0.5% in the general Dutch population aged 55 years and over (van Splunder *et al.* 2006). In addition, numerous studies have established that youths with visual impairments are less physically active than their peers without visual impairments (Longmuir and Bar-Or 2000; Houwen *et al.* 2009; Lieberman *et al.* 2010). Visual information is crucial for orientation and object detection for moving safely from one place to another. Because in people with a visual impairment this kind of information is reduced, being physically active can be challenging for them (Leemrijse and Schoenmakers 2016).

The combination of visual and intellectual disabilities makes being physically active even harder. Previous work (van der Putten *et al.* 2017) found that among people with profound intellectual and multiple disabilities (including visual impairments), 52% engaged on average in less than one motor activity per weekday. These authors concluded that in care facilities in the Netherlands, motor activation is not a structural part of the daily support for this group (van der Putten *et al.* 2017). In addition to people with profound intellectual disability, also people with more severe to mild intellectual disability have extremely low physical activity levels (Hilgenkamp *et al.* 2012b). Furthermore, the limited physical activity among people with visual impairments leads to a higher risk of developing health problems (Houwen *et al.* 2010; Lieberman *et al.* 2010). It can also lead to reduced alertness, which can in turn lead to decreased happiness and well-being (Cavill *et al.* 2006). The impact of limited physical activity on health and well-being outcomes makes it imperative for people with visual and intellectual disabilities to become more active.

Promoting physical activity among people with visual and intellectual disabilities can be challenging because of low participation rates. There may be a number of reasons for this. First, the intervention may not be adjusted to the interest or level of intellectual disability. Second, measurements may not apply to this target group. Third, external reasons, for instance accessibility of the location or transport to the location may be more prevalent among this target group. One study of a structured physical and fitness program offered to persons with ID had a significant participation drop-out (van Schijndel-Speet *et al.* 2017). A review by Bartlo and Klein (2011) on the effects of physical activity programs for adults with ID showed that balance, strength and quality of life can be improved but that most of the included interventions were developed for people with moderate to mild ID because of the need to understand verbal instructions (Dijkhuizen *et al.* 2018). For this reason, people with more severe ID may need targeted solutions to encourage them to become more active. No interventions are known to the authors that specifically target people with both intellectual and visual disabilities and address the specific needs for physical activity associated with this combination of disabilities.

Interest is growing in the role of technology for promoting physical activity (Stephenson *et al.* 2017; Oliveira *et al.* 2020; Williams and Ayres 2020), including among people with visual and/or intellectual disabilities. For instance, Boffoli and colleagues (2011) established that youth with visual impairments enjoy being physically active through the use of exergames, such as video games that require large motions as input (Morelli 2011). Among people with intellectual disabilities Virtual Reality improved physical fitness significantly for persons with moderate intellectual disabilities (Lotan *et al.* 2009).

But, due to unintended biases, this was not found for persons with severe intellectual disabilities (Lotan *et al.* 2010). Research to date on technological solutions for the promotion of physical activity has focused mainly on people with visual impairments or intellectual disability, rather than on those with both visual and intellectual disabilities.

Given the specific and complex needs of people with ID and visual impairments, a new technological device has been developed, called the Light Curtain. In the intervention design, the needs of the target group have been taken into account in the following ways: (1) it makes it possible for people with ID and visual impairment to experience success, (2) it provides sound as feedback to compensate for the impaired visual abilities and (3) the visual input includes simple figures and bright, strong colours with a high contrast. The Light Curtain relies on Kinect technology, which reacts to movement with light, colour and sound effects. Specifically, light, colour and sound are evoked if an individual moves in front of the Light Curtain. These effects can be experienced as rewarding, thereby encouraging more movement. The current study was conducted to gather preliminary evidence regarding whether the Light Curtain stimulates people with both visual and intellectual disability to become more physically active and the Light Curtain's potential effects on well-being.

## Methods

### Design

A randomised multiple baseline design was used to study the effect of using the Light Curtain on activity and well-being among individuals with a visual and intellectual disability. Data collection was performed in the following stages: collecting information on participant demographics (including sex, age, level of visual impairment, ID and mobility), a baseline phase and an intervention phase (Table 1). Participants were provided with a number when consent forms were received and then randomly assigned to one of the three groups of baseline length (Bulté and Onghena 2009). An independent person not otherwise associated with the study performed the randomisation for baseline length group assignment using a draw procedure. Seven measurements were taken during the baseline period and seven measurements were taken during the intervention phase.

### Participants

Nine adults participated in the study. Originally, the study involved 10 participant of which one was a 4-year-old child, which was excluded from the data analyses because of the different stage in life than the adults. All participants were residents of group homes run by Bartiméus, a Dutch organisation that provides support and care for persons with visual or visual and intellectual disabilities. Classification of visual impairment and ID was determined based on the International Classification of Diseases 10 (WHO 2004), with a severe visual impairment defined as visual acuity worse than 6/60 and moderate visual impairment as visual acuity worse than 6/18. Regarding the severity of ID, the following classifications were used: severe, defined as IQ 20–34 and an adult developmental age of 3–6 years; and moderate, defined as IQ 35–49 and an adult developmental age of 6–9 years. The participants all had a severe ($n$ = 3) to moderate ($n$ = 6) visual

**Table 1** Randomised multiple baseline design with varying baseline lengths over a period of 8 weeks

| | | Time period | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Group** | **Participants*** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| I | 3, 5, 9 | A | B | B | C | C | C | | |
| II | 4, 7, 2 | A | B | B | B | C | C | C | |
| III | 8, 1, 6 | A | B | B | B | B | C | C | C |

*Randomly selected time for baseline; A = demographics; B, baseline = care as usual; C, intervention = Light Curtain.

impairment and an IQ between 20 and 50 (WHO 2004). To be eligible for inclusion, participants had to be able to move their arms and to understand simple instructions, such as: step forward and step backwards. People who were blind or had an IQ below 20 or above 50 were excluded, as were those with severe illnesses and those who had used the Light Curtain before. People who met the inclusion criteria were entered into the study only if their legal representative had signed an informed consent document. Participant characteristics are shown in Table 2.

## Intervention

The Light Curtain is a 2 by 3 meter screen that can be lit up with light-emitting diodes. The Light Curtain can be connected to a computer (such as a laptop or desktop personal computer) using Kinect technology for playing exergames. While a participant is moving in front of the screen, the computer follows the movements through the Kinect technology and gives visual and auditory feedback A logic model of the Light Curtain and its effect on the participant is depicted in Figure 1. During the developmental process of creating the Light Curtain a prototype was created and tested by volunteers with intellectual and developmental disabilities and by professionals. The main improvements made on the prototype were adding more sounds to the feedback of the games and adding a white screen over the LED-screen (in order to protect the LEDs and participants and to defuse the light projected by the LEDs).

The Light Curtain contains nine games. In one game, for example, participants can earn points by reaching towards balls as they appear on the screen, hitting and popping them and causing the balls to shatter in an engaging manner (with colours and twinkling sounds). Each game has four difficulty levels. Several settings can be adjusted, including size and contrast of the visual stimuli, the speed at which they appear (pace), the time participants are allocated to react to the stimuli (appearance) and volume (Gasperetti *et al.* 2010).

In the course of 3 weeks, participants had seven sessions with the Light Curtain, each lasting between 15 and 30 min and including three games. The Light Curtain was located in a gymnasium on the same location where the participants lived. During the assessment, the participant and the researcher or research assistant were the only persons in the room. The researcher or research assistant gave participants an explanation of how the Light Curtain works ('The computer will recognize you and follows your movements'). This explanation was given while the first game was started, in which participants could see their body appear as a stick-figure on the curtain that moved as they themselves moved. Every session always started with this stick-figure game. After playing this game, participants could choose a second game from among four options that followed their movements. For instance, one game allowed them to paint the screen in one or more colours by moving their body. Finally, for the third game in a session, participants again could choose one game from among four options, in this case a game in which they moved towards a target (such as the game with the balls that need to be popped). Choices were posed matching their communication skills. All participants participated in and completed the sessions they were

**Table 2** Participant characteristics

| Participant | Sex | Age | Visual impairment | Intellectual disability | Mobility level |
|---|---|---|---|---|---|
| 1 | Female | 60 | Moderate | Severe | Able to walk |
| 2 | Male | 67 | Moderate | Moderate | Able to walk |
| 3 | Female | 68 | Moderate | Moderate | Wheelchair user |
| 4 | Male | 55 | Moderate | Moderate | Able to walk |
| 5 | Female | 63 | Severe | Moderate | Able to walk |
| 6 | Female | 50 | Moderate | Severe | Able to walk |
| 7 | Male | 61 | Severe | Moderate | Able to walk |
| 8 | Male | 38 | Moderate | Moderate | Wheelchair user |
| 9 | Male | 58 | Severe | Severe | Able to walk |

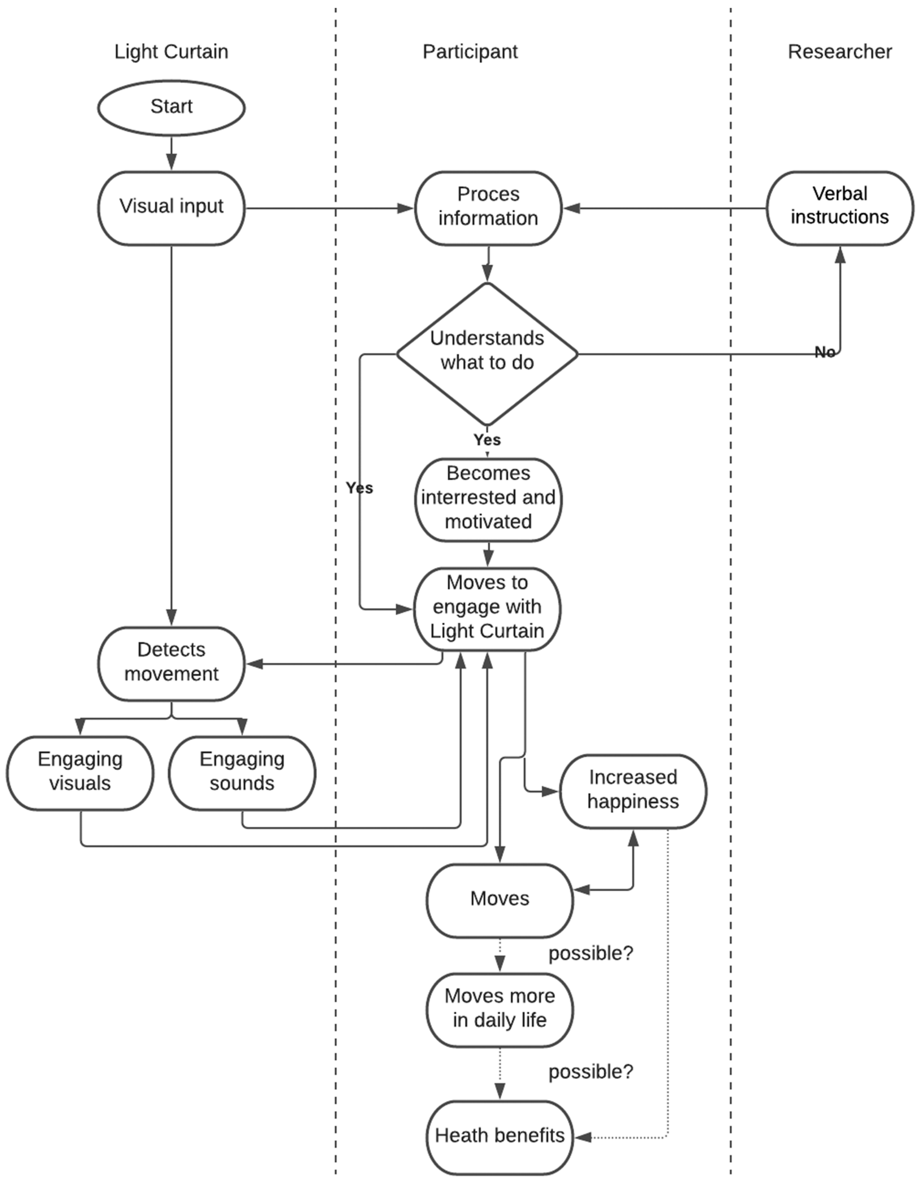


**Figure 1.** Logic model of the Light Curtain

assigned with the Light Curtain. Mean time spent engaging with the Light Curtain was 14 min and during this timeframe 3 to 5 games were played.

## Procedure

After the first author screened the medical files of people with a visual and intellectual disability living in Bartiméus group homes, 32 people were found to match the inclusion criteria. Thereafter, behavioural psychologists familiar with the selected potential participants were asked for more recent information on inclusion and abilities, leading to the exclusion of six potential participants, for example, due to illness. Finally, 26 persons who met the inclusion criteria were considered potential participants.

An information letter regarding the study was sent to the legal representatives of these potential participants, along with an informed consent document, which 13 legal representatives returned. Next, a simplified information letter with pictograms and pictures was provided to each potential participant to ask if they would like to participate. Ten individuals with a visual and intellectual disability signed this consent document and were therefore included in this study. Order in which signed informed consent forms were received determined participants' study number.

Next, demographic information regarding sex, age, level of visual impairment, degree of intellectual disability and mobility level was gathered from medical files. Then, an intake was conducted with caregivers regarding the participants' daily schedule to determine when, where and which activities would be observed during the baseline care-as-usual measurements. Some examples of activities that were observed during the baseline period include listening to or making music, doing (jigsaw) puzzles, performing craft activities (like knitting or making a mosaic), sorting or shredding (old) paper and riding an (electronic) wheelchair or bike. Seven baseline measurements were recorded at 2, 3 or 4 weeks, depending on the randomly assigned group (Table 1). Each participant had seven intervention measurement points during the 3 weeks of engaging with the Light Curtain.

During the baseline and intervention measurements, data were collected using a wireless multi-sensor wristband, the Empatica E4 wristband (Garbarino *et al.* 2014). The researcher or research assistant first put the device on the wrist of the participant's dominant hand, turned it on and conducted a video recording of 15 to 30 min.

This study was conducted in agreement with the Declaration of Helsinki. The Medical Ethics Committee of the Vrije Universiteit Medical Centre Amsterdam (project number: 2019-164) and the Scientific and Ethical Review Board of the Faculty of Behaviour & Movement Sciences, Vrije Universiteit Amsterdam, declared that the research proposal complied with the ethical guidelines of the faculty (project number 2018-170R1).

## Outcome measures

### *Physical activity*

Movement data were collected with a triaxial accelerometer embedded in the Empatica E4 wristband (Garbarino *et al.* 2014). The Empatica E4 wristband collects data via four embedded sensors: a photoplethysmograph, electrodermal activity sensor, a triaxial accelerometer and a temperature sensor. The wristband has been used successfully to measure movement in previous studies involving persons with dementia (Perugia *et al.* 2018). Data from the wristband were analysed from minutes 3 through 10 of observation, which was chosen to ensure sufficient data for analysis and resolution of start-up problems within the first 3-min period. For analysis of the triaxial accelerometer data, the mean variability for each direction ($x$, $y$ and $z$ axes) was calculated, as was the total magnitude of deviation.

Video recordings of participants performing care-as-usual activities and video recordings of participants engaging with the Light Curtain were used to score the frequency and duration of movement and activation in both settings. The amount of movement and activation in the recordings was determined according to subscales of the Happiness Feature Score (HFS) (Prins *et al.* 2009). The HFS is a coding scheme based on the operationalisation of happiness by (Lancioni *et al.* 2002) and includes five subsections covering facial expressions, body movements, hand movements, physical contact and sound. For each subsection, the frequency of specific behaviours was scored (Appendix A). The subsections covering movement, hand movement and sound the duration of the behaviour in seconds was scored as well. Movement was operationalised as the frequency and duration of the subsection 'Movements' of the HFS. Activation was operationalised as a sum of the frequency and duration of the subsections for movements, hand movements, physical contact and sound.

### *Well-being*

The video recordings were also used to determine participant well-being. The HFS (Prins *et al.* 2009) and the Arousal and Valence Scale (Frederiks and Sterkenburg 2017) were used to score indices of happiness and alertness. For each subsection on the HFS, the frequency of specific behaviours was scored. The AVS results indicate the alertness of a participant based on subscales for arousal and valence. The arousal score covers the amount of excitement on a scale of 1 (very low) to 6 (very high). The valence score indicates if the excitement is positive or negative. Valence scores range from −6 (highly negative) to 6 (highly positive; Appendix B).

Videos of the participants performing care-as-usual activities and engaging with the Light Curtain were scored using the HFS and AVS from minutes 3 through 10. Three independent observers (two undergraduates and one master's student of behavioural psychology) scored the videos. Scoring of the atypical behaviour of persons with visual impairments and intellectual disabilities requires training before raters can score the behaviour. All three observers were trained on the scoring instruments until they reached a good consensus (a Cohen's kappa of at least 0.75) and were considered reliable in their scoring.

## Statistical analysis

A visual inspection using graphs was first applied to the results for each participant. Then the Wilcoxon signed-rank test was used to determine a significant differences ($\alpha$ = 0.05) between care-as-usual and intervention results for each participant. Furthermore standardised mean different effect size (*d*) was used to determine effect sizes. Interpretation of the *d* scores for effect are: small effect size: .20–.49; medium effect size: .50–.79; large effect size: .80 and above (Kotrlik *et al.* 2011). Because we only had one child among our participants, we excluded this participant. The results of the nine single cases were combined into a meta-analysis for an overall average effect size using *P*-values. For every *P*-value, a natural logarithm was determined. The sum of the natural logarithms was then multiplied by −2. In cases in which the change was in an unexpected direction, a *P*-value of 0.5 was used, regardless of the actual *P*-value (de Weerth and van Geert 2002). The result was a chi-squared deviation, with twice the number of *P*-values as the degrees of freedom. Data were analysed using Excel and IBM Statistical Package for Social Sciences (SPSS) version 25.

# Results

## Physical activity

Physical activity as measured with the accelerometer significantly increased when participants engaged with the Light Curtain compared with performing care-as-usual activities (Figure 2). The meta-analytically combined *P*-values for total

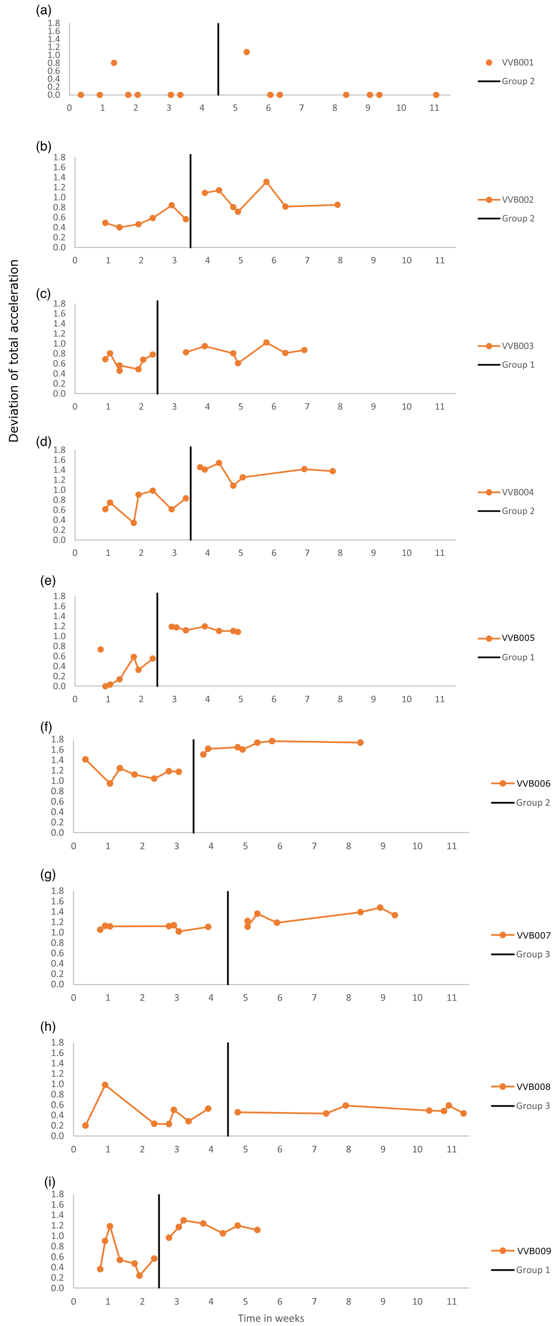


**Figure 2.** Deviation of total acceleration during the baseline (before the vertical line) and intervention sessions (after vertical line) per participant (a till i stands for participant number 1 till 9). [Colour figure can be viewed at wileyonlinelibrary.com]

acceleration (combined $\chi^2$ deviation = 52.19; $P < 0.001$) increased significantly in the intervention phase compared with the baseline measurements. The combined result of the Wilcoxon signed-rank test *P*-values on the movement and activation subscales of the HFS (movement, combined $\chi^2$ deviation = 17.10; activation, combined $\chi^2$ deviation = 17.92) did not reveal a significant difference between intervention and care as usual. There also was not a significant difference for scores of duration of movement and activation (movement, combined $\chi^2$ deviation = 17.24; activation, combined $\chi^2$ deviation = 16.18). Table 3 shows the mean scores, *P*-values and effect sizes for acceleration, and Table 4 shows the mean scores for the HFS movement and activation subscales (frequency and duration).

For participants 2, 3, 4, 5 and 9, acceleration was significantly greater in the intervention versus baseline phase, whereas for participants 6, 7 and 8, the increase was not significant. Most of the effect sizes were large, one effect size was medium. Participant 1 was excluded from this analysis, having only worn the wristband twice, once for a care-as-usual measurement and once during playing with the Light Curtain. Thus, data for this participant were insufficient for inclusion in the analysis. The standard deviation was higher for the baseline measurements than for the intervention measurements.

**Table 3** Mean, standard deviation (SD) and effect size (ES) of the total amount of deviation in acceleration during the baseline and intervention phases, per participant

| Participant | Acceleration baseline (SD) | Acceleration intervention (SD) | *P* (ES (*d*)) |
|---|---|---|---|
| 1 | 0.56 | 1.13 | - (NA) |
| 2 | 0.50 (0.12) | 0.93 (0.26) | 0.02* (2.06) |
| 3 | 0.62 (0.17) | 0.81 (0.10) | 0.02* (1.36) |
| 4 | 0.66 (0.24) | 1.34 (0.10) | 0.02* (3,70) |
| 5 | 0.32 (0.24) | 1.11 (0.04) | 0.02* (4.80) |
| 6 | 1.15 (0.26) | 1.49 (0.15) | 0.06 (1.60) |
| 7 | 1.03 (0.18) | 1.23 (0.15) | 0.06 (1.21) |
| 8 | 0.39 (0.26) | 0.49 (0.08) | 0.40 (0.55) |
| 9 | 0.54 (0.39) | 1.15 (0.12) | 0.03* (2.11) |

Note: Effect size (*d*); small effect size: .20–.49; medium effect size: .50–.79; large effect size: .80 and above (Kotrlik *et al.* 2011). NA = no available SD due to only one data point pre-intervention and post-intervention.
*Significant.

A closer look at the separate axes of acceleration, especially the vertical displacement, revealed a large difference between baseline and engaging with the Light Curtain ($\chi^2$ = 51.82; $P < 0.001$) (Figure 3).

## Well-being

A significant difference between the baseline and intervention phases was not found for well-being as measured with the HFS. Positive excitement did significantly increase in the intervention phase in comparison to baseline. Specifically, the meta-analytically combined *P*-values for arousal (excitement) (combined $\chi^2$ deviation = 42.50; $P < 0.001$) and valence (positive) (combined $\chi^2$ deviation = 43.16; $P < 0.001$) showed a significant increase in the intervention compared with the baseline phase. The combined result of the Wilcoxon signed-rank test *P*-values on the HFS (combined $\chi^2$ deviation = 21.68) did not show a significant difference between intervention and baseline. Table 5 lists the mean scores, *P*-values and effect sizes for the HFS and arousal and valence.

# Discussion

In this randomised multiple baseline study, we explored the effect of the newly developed Light Curtain on physical activity and well-being among people with visual and intellectual disabilities. The results showed that physical activity and positive excitement were higher when engaging with the Light Curtain in comparison to care-as-usual activities, including listening or making music, doing a (jigsaw) puzzle, performing craft activities, sorting or shredding of (old) paper and riding an (electronic) wheelchair or bike. This result is in line with findings from previous studies using exergames to improve physical activity in youth with visual impairments (Morelli 2011). The current study, however, is to our knowledge the first to specifically measure these outcomes in an intervention designed for people with both visual and intellectual disabilities. Therefore, these results represent the first indication that physical activity and positive excitement can be increased with an intervention that specifically targets this population.

Among the participants, acceleration was to a large extent seen in the vertical direction, a finding of

**Table 4** Mean, standard deviation (SD) and effect size (ES) of the activity subscale, duration of the activity and movement subscales, and duration of movement based on HFS during the baseline and intervention phases, per participant

| Participant | Activity baseline (SD) | Activity intervention (SD) | *P* (ES (*d*)) | Duration activity baseline (SD) | Duration activity intervention (SD) | *P* (ES (*d*)) |
|---|---|---|---|---|---|---|
| 1 | 58.71 (21.41) | 50.57 (12.37) | 0.50 (−0.46) | 104.29 (40.91) | 210.86 (193.58) | 0.24 (0.76) |
| 2 | 12.71 (14.94) | 11.29 (8.98) | 0.50 (−0.12) | 44.43 (85.69) | 14.29 (12.15) | 0.50 (−0.49) |
| 3 | 11.00 (8.29) | 27.43 (6.40) | 0.02* (2.22) | 17.86 (27.76) | 30.29 (28.42) | 0.46 (0.44) |
| 4 | 35.43 (21.63) | 79.57 (134.62) | 0.61 (0.46) | 75.71 (71.82) | 39.57 (17.17) | 0.50 (−0.69) |
| 5 | 20.00 (7.92) | 20.00 (17.59) | 1.00 (0.00) | 176.57 (189.92) | 64.86 (75.30) | 0.50 (−0.77) |
| 6 | 34.71 (28.45) | 6.57 (4.72) | 0.50 (−1.38) | 139.43 (115.35) | 23.29 (26.72) | 0.50 (−1.39) |
| 7 | 4.29 (5.68) | 5.14 (3.93) | 0.69 (0.18) | 20.86 (27.13) | 18.14 (17.35) | 0.50 (−0.12) |
| 8 | 15.71 (8.90) | 12.57 (4.32) | 0.50 (−0.45) | 82.00 (53.81) | 46.57 (34.60) | 0.50 (−1.88) |
| 9 | 29.14 (12.13) | 36.86 (5.70) | 0.27 (0.81) | 420.00 (283.94) | 561.00 (165.81) | 0.18 (0.61) |

| Participant | Movement baseline (SD) | Movement intervention (SD) | *P* (ES (*d*)) | Duration movement baseline (SD) | Duration movement intervention (SD) | *P* (ES (*d*)) |
|---|---|---|---|---|---|---|
| 1 | 4.86 (3.76) | 18.00 (10.46) | 0.02* (1.67) | 11.00 (20.50) | 144.71 (137.89) | 0.06 (1.36) |
| 2 | 8.29 (10.95) | 4.29 (3.45) | 0.50 (−0.49) | 33.43 (84.51) | 9.43 (7.32) | 0.50 (−0.40) |
| 3 | 0.86 (2.27) | 1.86 (1.95) | 0.50 (0.47) | 1.71 (4.54) | 4.57 (6.71) | 0.36 (0.50) |
| 4 | 4.14 (5.49) | 8.14 (14.55) | 0.68 (0.36) | 12.43 (25.19) | 12.14 (19.57) | 0.50 (−0.01) |
| 5 | 11.71 (5.02) | 14.71 (15.49) | 0.93 (0.26) | 171.14 (186.56) | 60.00 (75.92) | 0.50 (−0.70) |
| 6 | 9.86 (11.77) | 0.43 (0.79) | 0.50 (−1.13) | 83.71 (119.50) | 3.71 (6.58) | 0.50 (−0.95) |
| 7 | 0.14 (0.38) | 0.14 (0.38) | 1.00 (0.00) | 0.43 (1.13) | 0.29 (0.76) | 0.50 (−0.15) |
| 8 | 2.00 (3.70) | 0.29 (0.76) | 0.27 (−0.64) | 8.14 (14.82) | 1.14 (3.02) | 0.50 (−0.65) |
| 9 | 18.00 (8.79) | 2.43 (3.60) | 0.50 (−2.32) | 203.71 (96.89) | 37.86 (67.75) | 0.50 (−1.98) |

Note: Effect size (*d*); small effect size: .20–.49; medium effect size: .50–.79; large effect size: .80 and above (Kotrlik *et al*. 2011).
*Significant.

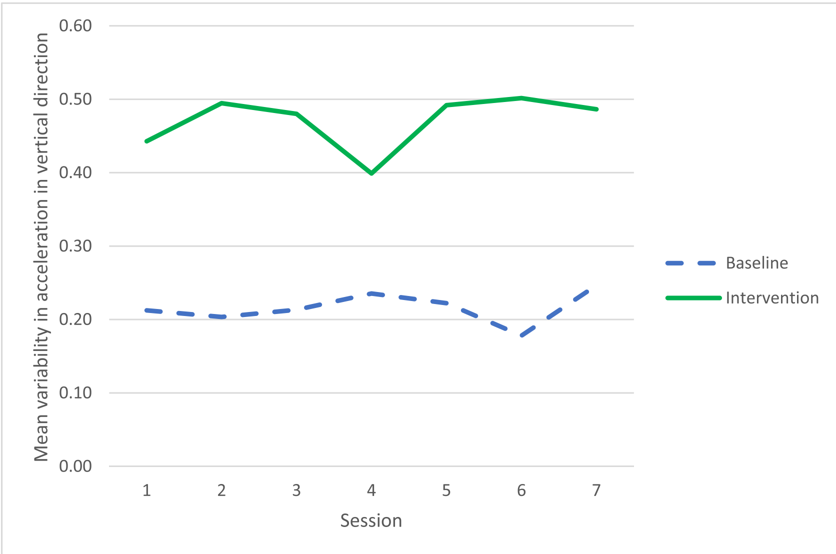


**Figure 3.** Vertical displacement during the seven baseline and intervention sessions for all participants. [Colour figure can be viewed at wileyonlinelibrary.com]

**Table 5** Mean, standard deviation (SD) and effect size (ES) for HFS, arousal and valence during baseline and intervention, per participant

| Participant | HFS baseline (SD) | HFS intervention (SD) | *P* (ES (*d*)) | Arousal baseline (SD) |
|---|---|---|---|---|
| 1 | 60.57 (23.66) | 59.00 (16.44) | 0.50 (−0.08) | 2.70 (0.39) |
| 2 | 12.71 (14.94) | 11.86 (9.12) | 0.50 (−0.07) | 2.10 (0.27) |
| 3 | 13.57 (8.87) | 29.14 (5.90) | 0.03* (2.07) | 2.49 (0.56) |
| 4 | 37.29 (22.92) | 89.71 (135.27) | 0.31 (0.54) | 2.33 (0.34) |
| 5 | 20.00 (7.92) | 26.57 (17.02) | 0.46 (0.49) | 1.52 (0.49) |
| 6 | 39.86 (29.67) | 9.71 (8.30) | 0.50 (−1.38) | 2.22 (0.51) |
| 7 | 4.43 (6.02) | 8.29 (5.65) | 0.20 (0.66) | 1.00 (0.00) |
| 8 | 28.71 (12.80) | 22.86 (5.15) | 0.50 (−0.60) | 2.18 (0.45) |
| 9 | 29.43 (12.26) | 36.86 (5.70) | 0.31 (0.78) | 1.97 (0.66) |

| Participant | Arousal intervention (SD) | *P* (ES (*d*)) | Valence baseline (SD) | Valence intervention (SD) | *P* (ES (*d*)) |
|---|---|---|---|---|---|
| 1 | 2.98 (0.69) | 0.20 (0.50) | 1.88 (0.49) | 2.05 (1.04) | 0.31 (0.21) |
| 2 | 2.44 (0.57) | 0.04* (0.76) | 0.99 (0.03) | 2.11 (0.49) | 0.02* (3.23) |
| 3 | 2.23 (0.24) | 0.50 (−0.60) | 1.68 (0.51) | 1.77 (0.50) | 0.55 (0.18) |
| 4 | 3.45 (0.46) | 0.02* (2.77) | 1.58 (0.41) | 3.03 (0.71) | 0.02* (2.50) |
| 5 | 1.89 (0.31) | 0.04* (0.90) | 0.76 (0.70) | 1.48 (0.52) | 0.03* (1.17) |
| 6 | 2.42 (0.35) | 0.46 (0.46) | 1.94 (0.79) | 1.97 (0.60) | 0.99 (0.04) |
| 7 | 2.35 (0.69) | 0.02* (2.77) | 0.43 (1.04) | 2.45 (0.72) | 0.02* (2.26) |
| 8 | 2.19 (0.13) | 0.80 (0.03) | 2.23 (0.45) | 2.32 (0.15) | 0.55 (0.27) |
| 9 | 2.53 (0.40) | 0.03* (1.03) | 0.88 (1.99) | 2.38 (0.71) | 0.03* (1.00) |

Note: Effect size (*d*); small effect size: .20–.49; medium effect size: .50–.79; large effect size: .80 and above (Kotrlik *et al.* 2011).
*Significance.

significant clinical relevance. People with visual impairment lack the visual input needed to stand up straight, so that they often take on a supine position. de Pádua *et al.* showed this difference in posture in children with visual impairment, reporting that they have more head tilt, a larger thoracic kyphosis and reduced lumbar lordosis compared with children without visual impairment (de Pádua *et al.* 2018). In clinical practice, referral for physiotherapy to improve posture in people with visual impairment is often provided because having an upright posture helps prevent neck and back pain. In this context, the current work offers an initial indication that the Light Curtain could be helpful in stimulating an upright position in people with visual impairment.

The higher positive arousal found in our participants provides additional evidence for the relationship between being physically active and alertness in this population. A higher positive arousal can also be an indication of a higher engagement. Engagement is defined by Perugia *et al.* as the psychological state of well-being, enjoyment and active involvement that is triggered by meaningful activities and that causes people (with dementia) to be enraptured by the activity, more energetic and in a more positive mood (Perugia *et al.* 2018). They have developed a model of engagement that can be measured using video observations combined with the use of technology such as sensors for biomarkers (Perugia *et al.* 2020). This use is based on the fact that with increased arousal, the autonomic nervous system is activated. This activation can be captured through monitoring biological signals for heart rate, skin conductance and skin temperature. Future research with physiological measures such as heart rate, skin conductance and skin temperature can confirm our results of positive arousal observed with the Arousal and Valence Scale.

A significant increase in happiness, as measured with the HFS, was not found in the current study. A possible explanation could be that happiness, as a complex concept, can be difficult to measure in this population. It has been found that indices of happiness in people with profound multiple disabilities are smiling, laughing, vocalising and producing excited head or arm movements (Lancioni *et al.* 2002). The HFS was used in the current study with participants who have severe to moderate intellectual and visual disabilities, which were not the originally targeted group for the HFS, given that it was developed for people with profound multiple disabilities (Lancioni *et al.* 2002). The HFS was considered the best suitable option for measuring happiness because an observational score better fits the population of people with visual and intellectual disabilities than do usual questionnaires for measuring happiness in people without disabilities. Using indices of happiness as the only measure of happiness might be insufficient or inadequate in many cases (Lancioni *et al.* 2002). Because the participants were able to understand simple instructions, in future research, the possibility of self-report can be explored using for example methods as carried out by Dee-Price *et al.* (2021). Thus, despite a clear relationship between higher physical activity and happiness (Zhang and Chen 2019), it can be challenging to capture that relationship with the HFS in people with intellectual and visual disabilities. Future studies should consider using additional measurements for happiness in this population.

The acceleration data measured at baseline showed larger standard deviations than acceleration measured during the intervention phase. A possible explanation is that the care-as-usual activities measured at baseline were more varied (ranging from sitting and listening to music to riding a bike or a wheelchair outdoors) than playing with the Light Curtain (same room, same kind of activity). Including a variety of activities in the baseline phase was a deliberate choice because we sought to measure the difference in outcomes when engaging with the Light Curtain in comparison with the normal daily life activities of the participants. This choice might, however, have resulted in a non-significant effect for participants 6, 7 and 8, for whom we may have included more active care-as-usual activities in this study. On the other hand, it is possible that these participants could simply have been less interested in the Light Curtain. This population is known for its diversity and earlier research has also identified variability in alertness and affective behaviour in response to an interactive ballgame compared with watching television (Embregts *et al.* 2020). Future research should focus on comparing the Light Curtain with other controlled activities.

Although earlier studies have shown that physical activity among people with ID can be validly measured with pedometers (Hilgenkamp *et al.* 2012a), accelerometery was deemed more suitable for the current study because of the inclusion of people in wheelchairs. Pedometers rely on cadence of the gait cycle and are not suitable for measuring movement among people in wheelchairs.

The movement subscale of the HFS did not show a significant difference between the Light Curtain intervention and care-as-usual activities, but the accelerometer data did show a difference. This divergence supports the assumption that the HFS might not be the best instrument for measuring well-being in this population. Alternative methods such as biomarkers, which measure this outcome more objectively, may be needed to obtain a better picture of well-being in people with intellectual and visual disabilities (Vos *et al.* 2012). Alternatively, another outcome measure for well-being may be more suitable, such as quality of life measured with a questionnaire such as the Intellectual Disability Quality Of Life (Hoekman *et al.* 2001) or the San Martín Scale (Verdugo *et al.* 2014). Earlier studies have shown that dance and movement therapy improved well-being in adults with ID (Barnet-Lopez *et al.* 2016; Lirola *et al.* 2020). Another possibility is that the Light Curtain should be used in a different way to have an effect on well-being and needs to be adapted more to individual preferences to increase happiness levels for people with visual and intellectual disabilities. Using the Light Curtain together with a friend, incorporating images into the Light Curtain, using sounds that bring up positive memories or using images of family could make the experience more personal and induce more happiness. The way in which the Light Curtain could be used to induce happiness among people with visual and intellectual disabilities is worth exploring in more detail in further research.

Although we did find a significant increase in physical activity and positive excitement from playing games with the Light Curtain in people with visual and intellectual disabilities, the sample size was small ($n = 9$). Therefore, a generalisation of the research findings to the heterogeneous group of people with visual and intellectual disabilities is limited. The current study can thus be viewed as a pilot study, providing preliminary results only. Furthermore, we did not look at the possible effects of playing with the Light Curtain in the long term. Because even light physical activity increases are associated with health benefits (Amagasa *et al.* 2018) it would be worthwhile to understand if over time people continue to engage with the Light Curtain and if the positive effects observed in the current study are sustained in the long term (over days, weeks or months). Possible health benefits could then be monitored, for instance with Heart Rate recovery. Long-term research involving a follow-up period in a larger sample is required to confirm our results. Finally, people with visual impairment and intellectual disabilities are not likely to use the Light Curtain on their own, and the participants in the current study indeed were living in care facilities and receiving care from professional caregivers. It is therefore also important in future research to understand the context of using the Light Curtain, including caregiver involvement and acceptance of it in their care practices.

The group of people with ID is very heterogeneous, even within the sample of the current study, there was variance in terms of level of ID, visual impairment, mobility, communication skills and level of understanding of how the Light Curtain works. For example, five participants understood that when they moved, the figure on the screen moved as a result of their action. The others who did not seem to understand this action-reaction aspect of the Light Curtain, did in any case react to the light or sound changes and moved more as a response to them. The results of the current study indicate that the Light Curtain can be used to positively influence the level of physical activity and alertness in a diverse group of people with visual and intellectual disabilities even despite differences in level of understanding of how the light curtain works.

Although engaging with the Light Curtain was shown to increase physical activity and positive excitement in persons with visual and intellectual disabilities, the activity should be individually tailored to the participant. This is because the extent to which engaging with the Light Curtain meets the interests of participants is likely to influence the extent to which it has an effect on their happiness or well-being. Accordingly, tailoring should be carried out based on the preferences of participants, by providing participants opportunities to choose the games they play. In this study the way that participants indicated their game preference was different for each participant. Some were able to tell what they would like to play by choosing from two or more options, others indicated yes or no to a game given either verbally or non-verbally with emotional expressions. The most appropriate and effective ways that participants can indicate their preferences to allow tailoring is an important topic for future research.

## Implications

The use of a targeted intervention for physical activity promotion, such as the Light Curtain, could be an opportunity to increase physical activity levels and alertness in people with visual and intellectual disabilities. Using the Light Curtain stimulates activity in a vertical direction, which is of significant clinical relevance because more vertical movements can contribute to a more upright posture for persons with a visual impairment, helping to prevent neck and back pain complaints. Furthermore, this study confirms the importance of using physiological measures in assessing positive arousal of persons with visual and intellectual disabilities.

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## Conflict of interest

No conflicts of interest have been declared.

## Data availability statement

Research data are available on request.

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## Appendix A: Happiness Feature Scale Adapted

Observation list based on the indices of happiness in people with profound multiple disabilities.

Date video:

Observator:

| Time | Facial expression | | | Movements (excited) | | | Hand movements | | | Physical contact | | | Sound | | | Duration (s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Half smile | Smile | Exuberant smile | Sway upper body | Sway upper body and/or arms | Sway total body | Rotating on lap | Rotating on chest | Shake extensively | Search | Permit/ allow | Target | Laughing | Singing | Positive | |
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Based on previous work (Lancioni *et al.* 2002; Sterkenburg 2020)

Based on previous work (Lancioni *et al.* 2002; Sterkenburg 2020).

## Appendix B: Arousal & Valence Scale

Behaviour observations – scoring manual

I. Arousal

Arousal is a primitive force that activates behaviour (Pfaff *et al.* 2008). "An animal or human with a greater degree of generalised CNS [central nervous system] arousal (1) shows greater responsiveness to sensory stimuli in all sensory modalities; (2) emits more motor activity; and (3) is more reactive emotionally" (p. 14, Pfaff *et al.* 2008). We define arousal as the amount of emotion or tension a person experiences (both the positive tension of being excited and the negative tension of being stressed or upset). Low arousal is associated with a calm and relaxed state. High arousal is experienced when one is angry or excited.

1. Very low: The client is being passive and shows hardly any response to the interaction with the caregiver or to stimuli from the environment. The client is drowsy, asleep or absorbed in their own thoughts.

2. Low: The client shows (very) little response to the interaction with the caregiver or to stimuli from the environment but does express some emotion. The client is discontented/content and moves a little restlessly regardless of whether the motion expresses positive or negative valence. If the client does show responses, the responses are short, the client's attention to the interaction with the caregiver or stimuli from the environment wanes, and responses fail to appear when the interaction or the stimulus is repeated.

3. Moderately low: The client is alert and shows a mild expression of emotion (e.g. displeasure or interest). The client shows an active interest in the interaction or the provided stimuli and a response to these stimuli.

4. Moderately high: The client is alert and responsive to the interaction with the caregiver or to stimuli from the environment. The client expresses emotions, for example, through clapping hands, smiling, pulling their hand away from a toy or the caregiver or making whining sounds.

5. High: The client is alert and responsive to the interaction with the caregiver or to stimuli from the environment. The score fits a client who clearly expresses emotions regardless of the nature of the emotion (e.g. happiness, sadness, anger). The client can show this through, for example, laughing out loud, crying or screaming.

6. Very high: The client is overstrung and freaking out. The client has no control over their behaviour. The client may express this through yelling, raging, being aggressive towards the caregiver (e.g. kicking, hitting, biting) or injuring themselves (e.g. biting, scratching).

II. Valence

Valence is the value of the emotion or tension. It can be neutral, positive or negative. Negative valence varies from tired, bored, depressed, and miserable to frustrated, stressed, angry, and afraid. Positive valence ranges from sleepy, calm, relaxed, and content to happy, delighted, excited, and astonished.

−6. Very high negativity: The client expresses a lot of negative behaviour. The client is raging, ferocious, extremely frustrated, very scared or overstrung. The client has no control over their behaviour and is aggressive towards the caregiver. The client is crying out, destroying the environment, crying, inconsolable, shaking beyond control or severely self-injuring.

−5. High negativity: The client clearly expresses negative behaviour. The client is angry, frustrated, scared or stressed. The client shows mild aggressive behaviour towards the caregiver, yells/screams, throws objects away, breaks objects, cries, is shivering or self-injuring.

−4. Moderately high negativity: The client is severely irritated, frustrated, upset or slightly stressed. The client refuses to cooperate in activities or rejects interaction with the caregiver. The client walks away from the caregiver, firmly turns their back towards the caregiver or fends off the caregiver (e.g. pushing the caregiver away). The client firmly counteracts and opposes. The client vocalises protesting, frustrated or angry sounds or verbalises protest, frustration or anger. The vocalisations vary in tone and/or volume.

−3. Moderately low negativity: The client expresses irritation or mild frustration. The client rejects or evades certain activities through pushing or throwing objects away. The client rejects or evades interaction with the caregiver by turning their back towards the caregiver or through creating distance between themselves and the caregiver. The client counteracts and opposes. The client vocalises protesting, frustrated or irritated sounds or verbalises protest, frustration or irritation. The vocalisations are monotonously and/or low in volume.

−2. Low negativity: The client shows slightly negative behaviour. The client is bored, does not participate/cooperate in activities or evades interaction with the caregiver (for example, through pulling their hand from the caregiver's hand). The client vocalises or verbalises boredom, dissatisfaction or mild irritation.

−1. Very low negativity: The client shows slightly negative behaviour. The client is slightly bored, is disinterested in the interaction with the caregiver or the objects, and does not consider the interaction or the objects to be fun.

0. Neutral: The client does not show positive or negative emotion. The client is passive, unresponsive or deeply asleep.

1. Very low positivity: The client is calm and attentive. The client does not reject the interaction with the caregiver or the activities but is paying attention or shows a low level of interest.

2. Low positivity: The client is relaxed. The client shows little response to the activities and/or the interaction with the caregiver but does express interest in the activities and/or interaction with the caregiver. The client makes brief contact with the caregiver through a short touch or vocalising or verbalising monotonously and/or low in volume.

3. Moderately low positivity: The client is content and/or pleased. The client expresses positive emotion through smiling, responding to activities and/or interaction with the caregiver, participating actively, and/or requesting the caregiver's attention. The client connects to the caregiver through clear vocalisations varying in tone or verbalisations, and through being physically close to the caregiver or through touch, for example, taking the caregiver's hand.

4. Moderately high positivity: The client is joyful, excited or mildly amused. The client expresses this through laughing, clapping hands, vocalising in loud and varying tones or verbalising, imitating the caregiver or seeking (physical) closeness to the caregiver. The client reacts positively to activities and the interaction with the caregiver, is active, and takes initiative in establishing activities, connection with the caregiver or interaction.

5. High positivity: The client is excited, amused, and/or happy. The client is laughing elatedly, laughing out loud, beaming or showing enthusiasm (e.g. through clapping hands). The client reacts very positively to activities and the interaction with the caregiver, is active, and takes initiative in establishing activities, connection with the caregiver or interaction.

6. Very high positivity: The client is excited and/or astonished. The client is roaring with laughter, cannot control their enthusiasm, cannot sit still from excitement, shakes their hands and/or arms, claps their hands fast and loud, and vocalises or verbalises quickly and with elation.

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