Received: 26 March 2018 | Revised: 11 August 2019 | Accepted: 13 August 2019
DOI: 10.1111/jar.12668

ORIGINAL ARTICLE

JARID bild WILEY

Competencies for rating perceived exertion in amateur soccer players with and without intellectual disabilities

Gerd Schmitz[1,2] | Jakob M. Meis[1] | Matthias Hafferkamp[2] | Sabine Schmitz[3]

[1]Institute of Sports Science, Leibniz University Hannover, Hannover, Germany
[2]Institute of Sport Science, Carl von Ossietzky University, Oldenburg, Germany
[3]Special Olympics Germany in Lower Saxony e.V, Celle, Germany

Correspondence
Gerd Schmitz, Institute of Sports Science, Leibniz University Hannover, Am Moritzwinkel 6, 30167 Hannover, Germany.
Email: gerd.schmitz@sportwiss.uni-hannover.de

Abstract

Background: Perception of exertion is essential for self-regulation in sports. The ability to rate perceived exertion (RPE) is regarded as psychophysiological competence, although cognitive components of RPE are largely unknown. The present study tested the hypothesis that cognitive processing speed, perseveration and figural fluency correlate with RPE.

Methods: The present study tested relationships between the performance in neuropsychological tests and the competence for RPE assessed during soccer training in 30 adults with and 22 adults without intellectual disabilities.

Results: Mean correlation coefficients for RPE and heart rate differed significantly between participants with intellectual disabilities (r = .41) and participants without intellectual disabilities (r = .71). The variance of RPE could be partially explained by neuropsychological performance measures reflecting cognitive processing speed and perseveration and by age.

Conclusions: The results point to an impaired perception of exertion in people with intellectual disabilities, which can be partially explained by individual neuropsychological competencies.

KEYWORDS

barriers, cognitive processing speed, executive functions, intellectual disabilities, perceiving exertion, UN Convention on the Rights of Persons with Disabilities

1 | INTRODUCTION

The ability to perceive and rate physical exertion (RPE) is essential for the perceptual regulation of exercise intensity (de Koning et al., 2011; Ulmer, 1996). It is a psychophysiological competence enabling autonomous training as well as appropriate handling of reserves of energy (Thiel, Pfeifer, & Sudeck, 2018). A large body of literature shows that RPEs correlate highly with physiological parameters such as heart rate, oxygen consumption and lactate during exercise (e.g. Abe, Yoshida, Ueoka, Sugiyama, & Fukuoka, 2015; Borg, 1982). Strong relationships between RPE and cardiorespiratory as well as metabolic variables have been reported for different populations: children, young and older adults, and trained, untrained and sedentary persons, as well as for persons with obesity or coronary artery disease (Coquart et al., 2012; Demello, Cureton, Boineau, & Singh, 1987; Elsangedy et al., 2013; Groslambert & Mahon, 2006; Scherr et al., 2013). It has further been proposed that afferent signals from the musculature, tendons and joints contribute to RPE and that the perception of exertion emerges from the integration of afferent somatosensory signals. Growing evidence suggests that RPE also depends on cognitive factors (awareness, memory, attention and cognitive development), and it is hypothesized that RPE is either top-down regulated or generated through corollary discharge by the brain (Abbis, Peiffer, Meeusen, & Skorski, 2015; Eston, 2012; Groslambert & Mahon, 2006; Pereira, Souza, Fossati Reichert, & Caraca Smirmaul, 2014). Nevertheless, compared to physiological components of RPE, cognitive components of RPE are largely unknown.

If cognitive variables affect the perception of effort, it would be expected that people with cognitive or intellectual impairments have lower competencies with respect to RPE than people without impairments. On this point, empirical studies have provided equivocal results. Stanish and Aucoin (2007) showed that RPE from people with intellectual disabilities correlates with heart rate as well as from people without intellectual disabilities. Moreover, low-active older adults with mild cognitive impairment seem to be able to perceptually regulate exercise intensity as well as older adults without impairments (MacAuliffe et al., 2018). However, other authors reported that the ability to rate physical exertion indeed depends on the cognitive development status (Groslambert & Mahon, 2006; Rodriguez, Zambrano, & Manterola, 2016). Arnold, Ng, and Pechar (1992) showed that the coefficients of the correlations between RPE and heart rate are significantly lower for people with intellectual disabilities than for people without intellectual disabilities. The results contradict each other, probably because mild cognitive impairment and intellectual disability have multiple manifestations. Such categories might not be sensitive enough to understand cognitive contributions to RPE. It is deemed necessary to better understand the psychology of RPE by identifying its specific cognitive components (Watt & Grove, 1993). The aim of the present study was to investigate whether people with intellectual disabilities and without intellectual disabilities differ in how they rate perceived exertion and whether individual cognitive competencies can account for this difference.

Gibson et al. (2003) hypothesized that afferent signals from peripheral organs are integrated with non-sensory inputs to a percept of fatigue, which can be modified through shifts of the attentional focus. This is plausible considering that it is possible to consciously perceive either sensations from single organs or the overall internal state by shifts of attention (Haensel, Baumgärtner, Kormann, & Ennigkeit, 2016). Furthermore, there is empirical evidence that an external attentional focus induced by instruction alters RPE compared to an internal attentional focus (Lohse & Sherwood, 2011) indicating that attentional control is one of the cognitive components of RPE. Considering that the rating of perceived exertion requires an accumulation of multiple sensations into a single percept (afferent feedback theory) or the generation and perception of feedforward expectations (corollary discharge hypothesis; Pereira et al., 2014), RPE might also depend on information processing abilities. St Clair Gibson et al. (2006), p. 706) assume a central information control mechanism that processes and weights 'the enormous quantity of data from the external environment and from the different physiological systems of the body' and thereby determines RPE.

Attentional control and information processing capabilities represent two major components within a conceptual framework of cognitive executive control (Anderson, 2008). They are intertwined and tightly linked with cognitive flexibility and goal setting, which altogether represent cornerstones of behavioural control. Growing evidence suggests that executive functions are relevant for sports performance (Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012; Vestberg, Reinebo, Maurex, Ingvar, & Petrovic, 2017). Their possible role in self-perception and self-control of exercise intensity might be one factor amongst others, which contributes to this relationship. Furthermore, this might explain why some people with intellectual disabilities show a decreased competence for RPE, because intellectual disability coincides with reduced executive functions as inhibition, perseveration, fluency and processing speed (Bexkens, Ruzzano, d'Escury-Koenings, Van der Molen, & Huizenga, 2014; Danielsson, Henry, Rönnberg, & Nilsson, 2010; Inui, Yamanishi, & Tada, 1995; Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010).

1.1 | Hypotheses

In the present study, we tested the research hypotheses 'people with intellectual disabilities have an impaired perception of exertion and rate perceived exertion differently compared to people without intellectual disabilities' (Hypothesis 1) and 'cognitive processing speed and executive functions correlate with ratings of perceived exertion' (Hypothesis 2). Research Hypothesis 1 was operationalized to Hypothesis 1a, 'participants with intellectual disabilities have on average lower coefficients of the correlations between heart rate and RPE than participants without intellectual disabilities', and Hypothesis 1b, 'the slopes and the intercepts from inter-individual regression analyses between heart rate and RPE differ between participants with intellectual disabilities and participants without intellectual disabilities'. Research Hypothesis 2 was operationalized to 'measures of cognitive processing speed, perseveration and figural fluency explain inter-individual variance from the ratings of perceived exertion'.

According to Watt and Grove (1993), psychological factors of RPE might be most relevant in field compared to laboratory situations, which also might support their identification in an empirical study. Therefore, and in order to provide familiar testing situations for the participants, the hypotheses were tested in a field study with soccer teams, which were composed of players either without or with intellectual disabilities.

2 | METHOD

To recruit participants for the study, the authors contacted representatives from institutions for people with intellectual disabilities. The representatives informed the authors which participants could give their consent independently and in which cases the additional consent of the legal representatives were required. The authors and the sport coaches of the institutions informed the participants and in three cases also their legal representatives about the goals, methods and procedures of the study and asked for voluntary participation. All probable participants received one document in formal language and one document in plain language, in which the goals, procedures, the data acquisition, the rights of the participants and the obligations of the investigators were listed. The document in plain language was also read to the participants. All participants stated that they had understood the goal of the study as well as the methods and procedures and gave their verbal and written informed consent to the study. For three participants, the consent of their legal representatives was also required and obtained. All but one of the persons approached took part in the study. The study protocol was conducted in full accordance with the ethical principles of the World Medical Association Declaration of Helsinki (version 1964, including its later revisions). The study protocol and all documents had been independently reviewed and pre-approved by the local ethics committee of the Carl von Ossietzky University Oldenburg.

Thirty persons (mean age: 26.9 years, *SD*: 5.3 years) with intellectual disabilities participated in the study (group with intellectual disabilities). All of them had been previously classified by local expert committees as persons with intellectual disabilities. None of them had Down syndrome. Their mean performance in the number connection test assessing the fluency component of intelligence (Oswald, 2016) was nearly similar to the mean performance of an age-matched normative sample, which represented a sample of people with intellectual disabilities according to the International Statistical Classification of Diseases and Related Health Problems (ICD-10), category F7 (mean and *SD* study sample: 30 ± 13, mean normative sample: 33, $t(24) = -1.11$, $p = .277$). Twenty-two participants (mean age: 23.5 years, *SD*: 5.7 years) were without overt intellectual, psychic or cognitive impairments. They had been recruited from two regional sports clubs (group without intellectual disabilities). Their mean performance in the number connection test was not significantly different from an age-matched normative sample (mean and *SD* group without intellectual disabilities: 46 ± 9, mean and *SD* normative sample: 47 ± 11, $t(271) = -.42$, $p = .673$). All participants were amateur soccer players, regularly trained 1–2 times per week, and were experienced in competitive sports (leagues and tournaments).

2.1 | Cognitive performance tests

Cognitive abilities were assessed by two non-verbal paper–pencil tests, which are typically applied for neuropsychological diagnosis of cognitive impairments in children and adults. Both tests were administered in balanced order across participants. Five participants with intellectual disabilities decided not to participate in these tests.

The *number connection test* was applied to assess cognitive processing speed (Oswald & Roth, 1987). Participants were instructed to connect on a sheet of paper (DIN A4) circles with the numbers one to ninety therein as quickly as possible in ascending order. Consecutive numbers were located directly above, below, to the left, to the right or in a diagonal above or below each other. The test stopped after 30 s. The test determines cognitive processing speed in bit/s, which is regarded as fundamental cognitive component. It seems to be related to the fluency component of intelligence; accordingly, the test measure correlates on a medium-to-large level ($r = .40–.83$) with intelligence tests (Oswald & Roth, 1987; Salthouse, 2011).

The *five-point test* was applied as non-verbal fluency task originally developed by Regard, Strauss, and Knapp (1982). The participants received two sheets of papers (DIN A4) with forty rectangles per page. Each rectangle contained five points. The participants had to create a pattern within each rectangle by connecting two to five points. They were instructed to create as much different patterns as possible. Here, the 3-min HAMASCH version (Haid et al., 2002) was used. Dependent variables were the number of unique patterns, reflecting figural fluency, and the percentage of repeated patterns, reflecting perseveration (Spreen & Strauss, 1998; Tucha, Aschenbrenner, Koerts, & Lange, 2012).

2.2 | Soccer training

In a second session, all participants performed soccer training. Each player participated in a one-hour training session. Four coaches performed the training with the players with intellectual disabilities and two coaches the training with the players without intellectual disabilities. The players and coaches were familiar with each other. Each player performed his training with peers from his institution. The coaches were a priori instructed to train the participants with for them familiar contents and methods. Moreover, they should demand different levels of intensity and focus on technical training (passing, dribbling alone and against one opponent, shooting from a pass) as well as gameplay. The proportion of contents is shown in Table 1. Differences occurred with respect to movement coordination training, which was a typical training routine for twelve players without intellectual disabilities but only six players with intellectual disabilities. All other players performed dribbling and passing exercises instead. Marginal differences in training contents and proportions were accepted in order to test the participants in familiar training situations. This should avoid probable distractions allowing keeping the focus of attention to internal states during the rating of exertion. This procedure might be considered as ecologically valid. The training contents were discussed between investigators and coaches and

TABLE 1 Training contents for the players with and without intellectual disabilities

	with intellectual disabilities	without intellectual disabilities
Warm-up	18%	17%
Sprints	8%	8%
Movement coordination training	2%	7%
Passing and dribbling	31%	26%
Gameplay	36%	37%
Cooldown	5%	5%

defined a priori. During the training, the investigators did not exert influence on any of the training contents.

During training, all participants wore a breast belt for registration of heart rate frequency (acentas). Data were transmitted wirelessly to a laptop computer, which synchronized the data streams with a temporal resolution of 1 Hz and enabled to set markers contemporaneously for all team members or exclusively for one team member, to synchronize the start and end of the training sessions and to denote the points in time when perceived exertion was rated.

Subjective perception of exertion is typically evaluated on the basis of rating scales like the Borg Scale (Borg, 1982): athletes differentiate ten to fifteen exertion or fatigue levels verbally, or they point at numbers or images of a human in different bodily postures reflecting different states of exertion. In the present study, perceived exertion was assessed at nine times during training with the OMNI Scale for children (Robertson et al., 2000; Utter, Robertson, Nieman, & Kang, 2002), which had been previously been applied in studies with people with intellectual disabilities by Stanish and Aucoin (2007) and Chen, Ringenbach, Snow, and Hunt (2013). The OMNI Scale differentiates ten levels of exertion ranging from very, very weak (1) to very, very tired (10). Although the traditional Borg Scale has also been shown to provide sound results on RPE in people with intellectual disabilities (Arnold et al., 1992), the OMNI Scale might be more appropriate, because it further illustrates different grades of exertion by a caricature of a person in different states of exertion. These visual illustrations have been validated for RPE ratings in people with intellectual disabilities by Chen et al. (2013).

For the rating of perceived exertion, the investigators called each player to the sideline, asked how exerted (in German: 'wie angestrengt') he feels, and instructed him to verbalize his exertion and to indicate the perceived exertion by pointing on the OMNI Scale. The scale value was marked and verbalized by the investigator. The time of the rating was documented ($time_{RPE}$).

2.3 | Data processing

As recently shown by Hilgenkamp and Baynard (2017), peak heart rate seems to be lower in people with intellectual disabilities compared to people without intellectual disabilities. Therefore, heart rate was normalized to the individual peak heart rate (HRpeak). HRpeak was calculated according to a formula derived from a meta-analysis by Tanaka, Monahan, and Seals (2001), which considers a nearly linear relationship between peak heart rate and age expressed by.

$$\text{HRpeak} = 208 - 0.7 \times \text{age}.$$

If a higher heart rate than the calculated HRpeak was measured during training, the measured value substituted the calculated value.

In a next step, to classify physiological intensity of training and to compare load profiles between participants with and without intellectual disabilities, individual heart rate data were assigned to intensity zones. According to the American College of Sports Medicine, such a procedure allows differentiating metabolic states of the participants during training (Garber et al., 2011). In the present study, five zones were defined according to Hottenrott, Hoos, Stoll, and Blazek (2013) (zone 1: ≤60%; zone 2: >60 and ≤70%; zone 3: >70 and ≤80%; zone 4: >80 and ≤90%; and zone 5: >90% of the individual HRpeak). Moreover, training load was compared between people with and without intellectual disabilities by applying the summated heart rate zone method described by Edwards (1994). In this method, the durations spent in the heart rates zones are multiplied with the weighting factors 1–5; that is, the duration spent in zone 1 is multiplied with the weighting factor 1 and the duration spent in zone 5 is multiplied with the weighting factor 5. A summation of the adjusted scores results in the summated heart rate zone score (sHRz score).

2.4 | Statistical analyses

Normality distributions were tested with Kolmogorov–Smirnov tests. Cognitive performance data were compared between groups by one-way ANOVAs with the factor group.

To compare the profile of training intensity between groups, a two-way ANOVA with the factors group (with and without intellectual disabilities) and zone (1–5) was calculated. Sphericity assumption was tested with Mauchly's test; if significant, results were corrected according to the Greenhouse–Geisser procedure.

Complying with the procedures from the study of Arnold et al. (1992), correlations between heart rate and RPE were analysed by two different procedures. To determine each individual's competence for RPE, linear regression analyses were performed on the RPE and heart rate data normalized to HRpeak for each participant. Individuals' correlation coefficients *r* were used to compare RPE competence between groups by *t* test for independent samples. Furthermore, one inter-individual regression analysis was performed per group on individuals' RPE and heart rate data. Their slopes and intercepts were compared between groups by *t* test for independent samples. In contrast to the first analysis, the comparison of the inter-individual regressions allows analysing whether participants with and without intellectual disabilities differ in how they rate perceived exertion at different intensities. Since the intensity distributions differed marginally between groups over time (Figure S1) and the relationship between heart rate and RPE might be influenced by the factor time, the analyses were replicated with $time_{RPE}$ as covariate.

To test Hypothesis 2, multiple linear regression analyses were performed in a stepwise procedure backwards. In the first analysis, the dependent variable was the individual semi-partial correlation coefficient (r_s) from each individual's regression analysis between RPE and heart rate residualized by the covariate $time_{RPE}$. In the second analysis, the dependent variable was the root of the mean squared residuals (meanRes) of each participant from the inter-individual regression analyses between heart rate and RPE residualized by the covariate $time_{RPE}$. Predictor variables were cognitive processing speed, figural fluency, perseveration, age and unexplained intellectual disability. Unexplained intellectual disability corresponded to the group variable residualized by the former four variables in a discriminant analysis. For the regression analyses, the denominator degrees of freedom were reduced by 1 for each data processing step in the preceding procedures. Statistical analyses were performed with the software Statistica 12 (StatSoft Europe GmbH).

3 | RESULTS

3.1 | Cognitive variables

Figure 1 shows the results of the cognitive performance tests. As indicated by Figure 1a,b, participants with intellectual disabilities had significantly lower processing speed (F(1,45) = 21.63, p < .001, η^2 = .32) and reduced performance with respect to figural fluency (F(1,45) = 55.70, p < .001, η^2 = .55) compared to participants without intellectual disabilities. Both groups did not differ with respect to perseveration (Figure 1c; F(1,45) = 2.78, p = .102, η^2 = .06). The latter variable was not normally distributed and therefore linearized by natural logarithmic transformation: the outcome is shown in Figure 1d. Linearized perseverations were normally distributed. Group differences were now marginal and not significant (F(1,45) = .01, p = .825, η^2 < .01).

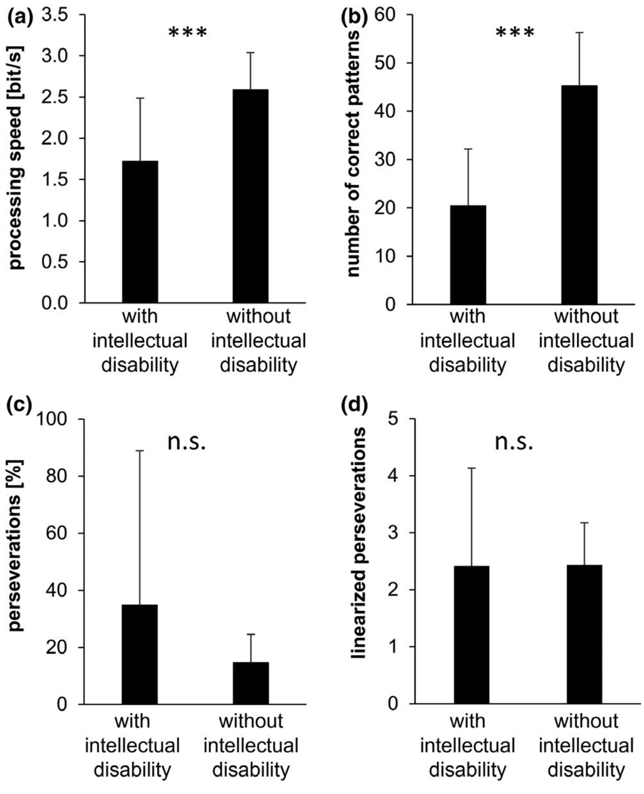

FIGURE 1 Results from the cognitive performance tests. Illustrated are means and standard deviations from people with and without intellectual disabilities. (a) Cognitive processing speed in bit/s from the number connection test; (b) number of unique designs from the five-point test reflecting figural fluency; (c) percentage perseveration from the five-point test; (d) linearized perseveration. Highly significant differences (p < .001) are represented by asterisk and non-significant differences by the abbreviation 'n.s.'

3.2 | Training intensity

Training durations differed inter-individually: on average, participants trained for 67.30 min (SD: 11.67). However, total training duration had no significant effect on any of the measured variables of the present study. Continuous measuring of heart rates allowed determining training intensity zones, which are illustrated in Figure 2. The major training volume was performed with submaximal intensities between 60% and 90% of the individual HRpeak. These zones had significantly larger training portions than zones 1 and 5 as confirmed by Tukey's post hoc test (each p < .01) to the significant ANOVA-effect zone (F(4,200) = 18.81, p < .001, η_p^2 = .27). On average, about 10% of training was performed at maximum intensities, but only 63% of the participants with intellectual disabilities and 67% of the participants without intellectual disabilities reached maximum intensities. The intensity profiles were quite similar across groups; only at a descriptive level, participants with intellectual disabilities performed slightly more at submaximal and less at maximal zones. Accordingly, neither the mean intensity profiles (training intensity × group: F(4,200) = .98, p = .397, η_p^2 = .02) nor the summated heart rate score sHRz (with intellectual disabilities: mean: 200.78, SD: 46.83; without intellectual disabilities: mean: 185.23, SD: 57.61; F(1,51) = 1.18, p = .283, η_p^2 = .02) differed significantly between groups. The intensity distributions differed marginally but significantly between groups over time (Figure S1); therefore, $time_{RPE}$ was used as a covariate in the subsequent analyses.

3.3 | Ratings of perceived exertion

Individual competence for RPE could be assessed for 30 participants with intellectual disabilities and 21 participants without intellectual disabilities by individual regression analysis between heart rate and RPE. For one participant without intellectual disabilities, heart rate data were not available. Figure 3 illustrates the individual regression lines. Whereas regressions in participants without intellectual disabilities (Figure 3a) were positive, inter-individually homogeneous and, for 19 from 21 participants, significant (p < .05), regressions of the participants with intellectual disabilities (Figure 3b)

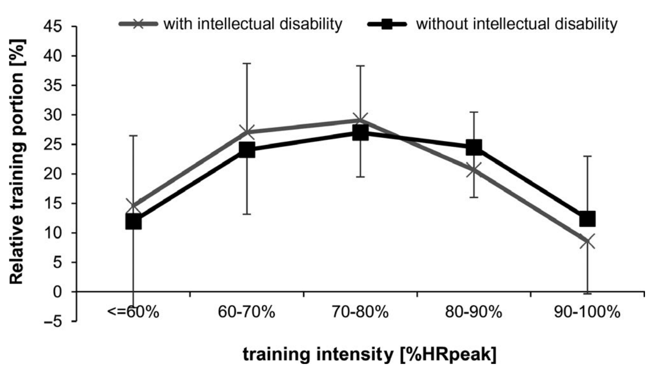

FIGURE 2 Relative training volume at five different training intensities in relation to the individual maximum heart rate (HRpeak). Displayed are means and standard deviations of participants with and without intellectual disabilities

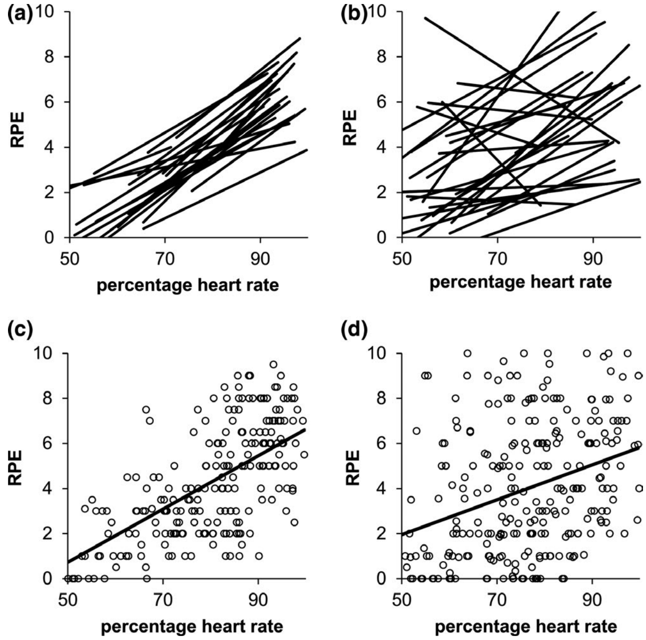

FIGURE 3 Relationship between normalized heart rate and ratings of perceived exertion (RPE) assessed with the OMNI Scale. Top, (a) Individual regression lines of the participants from the control group; (b) individual regression lines of the participants with intellectual disabilities. Bottom: Regression lines from the inter-individual correlations for participants without (c) and with (d) intellectual disability

were comparatively heterogeneous. They were significant for 14 from 30 participants only ($p < .05$). Here, a majority of regression lines were flatter than in the other group. Some of them even had negative slopes reflecting decreasing RPE values with increasing heart rate. Statistically, mean correlation coefficients differed significantly between groups ($t(49) = -2.85$, $p = .006$). They were lower in participants with intellectual disabilities (mean: .41, *SD*: .47) than in participants without intellectual disabilities (mean: .71, *SD*: .14). With $time_{RPE}$ as covariate, the coefficients r_s of the semi-partial correlations between heart rate and RPE still differed significantly between participants with intellectual disabilities (mean: .26, *SD*: .30) and participants without intellectual disabilities (mean: .60, *SD*: .23; $t(49) = -4.42$, $p < .001$). In contrast, the coefficients of the semi-partial correlation between $time_{RPE}$ and RPE did not differ significantly between groups (with intellectual disabilities: mean: .38, *SD*: .39; without intellectual disabilities: mean: .31, *SD*: .31, $t(49) = .76$, $p = .449$). In the group with intellectual disabilities, the mean correlation coefficient *r* and the mean semi-partial correlation coefficient r_s were significantly larger than zero (r: $t(29) = 4.83$, $p < .001$; r_s: $t(29) = 4.65$, $p < .001$).

The inter-individual regression lines are shown in Figure 3c,d. Regression analyses confirmed significant correlations between heart rate and RPE for both groups (group with intellectual disabilities: $r = .35$, $F(1,259) = 35.46$, $p < .001$; group without intellectual disabilities: $r = .64$, $F(1,222) = 150.96$, $p < .001$). However, as illustrated in Figure 3c,d, the slope was lower and the intercept larger in participants with intellectual disabilities (slope: .08, intercept: −1.91) than in participants without intellectual disabilities (slope: .12, intercept: −5.19). Those differences were statistically significant (slopes: $t(483) = -2.46$, $p = .014$, intercepts: $t(483) = 2.53$, $p = .012$). With $time_{RPE}$ as covariate, the slopes (without intellectual disabilities: .12, with intellectual disabilities: .04, $t(481) = 4.82$, $p < .001$) and intercepts (without intellectual disabilities: −5.48, with intellectual disabilities: −.95, $t(481) = 3.74$, $p < .001$) still differed significantly between groups.

In a next step, it was analysed whether the competence for RPE, per definition represented by the individual semi-partial correlation coefficient r_s, was related to age and cognitive performance. As perseveration was not normally distributed, the logarithmic-transformed perseveration value was used as predictor variable. A stepwise linear regression analysis backward for the individual r_s yielded significance for perseveration ($F(1,39) = 4.71$, $p = .036$, $\eta_p^2 = .10$), age ($F(1,39) = 8.78$, $p = .005$, $\eta_p^2 = .17$) and unexplained intellectual disability ($F(1,39) = 13.18$, $p < .001$, $\eta_p^2 = .24$), which together explained 40% of the variance from RPE ($F(3,39) = 9.27$, $p < .001$). The same analysis with meanRes as dependent variable, which reflects the residual of RPE not explained by heart rate and $time_{RPE}$, yielded significance for cognitive speed ($F(1,39) = 6.74$, $p = .013$, $\eta_p^2 = .13$) and unexplained intellectual disability ($F(1,39) = 6.56$, $p = .014$, $\eta_p^2 = .13$). Together, these variables explained 22% of the variance of the residuals from perceived exertion ($F(2,39) = 6.19$, $p = .005$).

4 | DISCUSSION

People with intellectual disabilities show very low levels of physical activity (Dairo, Collett, Dawes, & Oskrochi, 2016). To increase sports engagement, it is necessary to understand the barriers that impede sport participation (Jaarsma & Smith, 2017). A reduced perception of exertion could be a psychophysiological barrier for being physically active in people with intellectual disabilities. The present study investigated whether people with intellectual disabilities have an impaired perception of exertion and whether specific cognitive variables can account for this.

4.1 | Ratings of perceived exertion

Ratings of perceived exertion have been shown to correlate linearly with heart rate in a variety of populations (e.g. Elsangedy et al., 2013; MacAuliffe et al., 2018). In the present study, people without intellectual disabilities showed such correlations on the individual (Figure 3a) as well as on the inter-individual level (Figure 3c). In contrast, for only about the half of participants with intellectual disabilities, correlations between RPE and heart rate became significant. Accordingly, mean correlation coefficients were significantly lower in participants with intellectual disabilities than in participants without intellectual disabilities, which confirms Hypothesis 1 and replicates earlier findings from Arnold et al. (1992). Furthermore, the observation of the large inter-individual variability as well as the negative correlations for some participants (Figure 3b) replicates findings from other authors (Arnold et al., 1992; Chen et al., 2013; Stanish & Aucoin, 2007). Thus, on average RPEs seem to be lower in people with than without intellectual disabilities. However, as indicated by the inter-individual variability, RPE competences seem to depend largely on individual variables.

Inter-individual regression analyses focused on how perceived exertion was rated across participants of each group. For participants with intellectual disabilities, the slope of the regression line was flatter and the intercept larger than for participants without intellectual disabilities. The same phenomenon can be seen from a comparison of Figures 1 and 2 in the study from Arnold et al. (1992) who performed a laboratory experiment with a standardized exercise protocol. A detailed view at Figure 3d of the present study indicates that predominantly lower intensities were overrated, which would explain both lower slope and increased intercept. Such an effect does not necessarily mean that perception of exertion is only impaired at submaximal intensities: it can be expected that afferent signals increase exponentially at higher intensities and thus might be better perceived.

4.2 | Cognitive variables of RPE

RPE is understood as psychophysiological competence (Borg, 1982) and seems to be related to cognitive variables (Groslambert & Mahon, 2006; Gibson et al., 2003). The present study tested the hypothesis of correlations between the competence for RPE and cognitive competencies related to information processing in the brain. On the individual level, the quality of correlations between heart rate and RPE was related to perseveration, which was determined from the number of repetitions in the five-point test. Perseveration is attributed to cognitive executive control (Goebel, Fischer, Ferstl, & Mehdorn, 2009); therefore, this finding might reflect an impact of cognitive control of information processing on RPE.

At the inter-individual level, the variance of RPE residualized by heart rate and $time_{RPE}$ could be partially explained by cognitive processing speed. As participants with intellectual disabilities had significantly lower measures for processing speed than participants without intellectual disabilities, this finding indicates that they might have been overwhelmed by the amount of information on exertion and that they might not have been able to accumulate information to a single percept on exertion, which is necessary for RPE.

In the present study, cognitive processing speed and figural fluency, but not perseveration, differed significantly between people with and without intellectual disabilities. These results replicate findings from other authors on reduced performance of people with intellectual disabilities in fluency tasks (Danielsson et al., 2010) and findings on unimpaired performances in tasks that measure cognitive inhibition and perseveration (Bexkens et al., 2014; Lanfranchi et al., 2010). Accordingly, cognitive processing speed, but not perseveration, can partially explain the differences of RPE between participants with and without intellectual disabilities. However, the variable unexplained intellectual disability was a significant predictor in the regression analyses, which suggests that further variables contribute to the lower RPE in people with intellectual disabilities, which had not been assessed in the present study. Further research is needed concerning this matter.

The results do not allow any conclusions to be drawn regarding causality between cognitive variables and RPE. Pereira et al. (2014) describe bottom-up as well as top-down concepts for RPE: according to the corollary discharge hypothesis, RPE has a cognitive origin, whereas the afferent feedback hypothesis postulates that body signals are fused to a percept of exertion. The significantly lower coefficients of the semi-partial correlations between heart rate and RPE for players with intellectual disabilities compared to players without intellectual disabilities might indicate that they have lower competencies to perceive and/or rate afferent feedback. Furthermore, since the semi-partial correlations between $time_{RPE}$ and RPE were not significantly different, this finding might point to an impaired perception of acute exertion rather than to an impaired perception of fatigue. In the inter-individual regression analyses, RPE was residualized by heart rate and $time_{RPE}$. The group differences as well as the significant correlations between cognitive processing speed and the regression residuals might indicate that players with and without intellectual disabilities also differ with respect to a cognitive component of RPE that is independent from the perceptions of acute exertion or fatigue.

4.3 | Methodological limitations and recommendations for future studies

The study is subject to some limitations. It would be interesting to investigate in future whether physical fitness or sports success mediates the correlations between cognitive variables and RPE. Physically fit and successful athletes might have more experience in the perception of exertion. Unfortunately, inter-individual differences with respect to the physical state could not be considered in the present study, because these data were not available. However, research from Elsangedy et al. (2013) indicates that unfit and obese women rate exertion similar to women who are physically fit and of normal weight, indicating that fitness level plays a minor role.

Although all participants had experience with respect to league play and tournaments, their experience differed. Six of the players with intellectual disabilities belonged to one of the most successful national teams for players with intellectual disabilities. On average, even they showed a lower correlation between RPE and heart rate ($r = .58 \pm .26$) compared to participants without intellectual disabilities. Nevertheless, future studies might investigate these factors specifically.

Another aspect concerns the physiology of people with intellectual disabilities. Recently, Hilgenkamp and Baynard (2017) reported that people with intellectual disabilities have lower peak heart rates and lower peak oxygen uptake than people without intellectual disabilities, probably due to an altered autonomic cardiac regulation. A detailed view at Figure 2 of the present study indicates that training intensity profiles of participants with intellectual disabilities showed a slight deviation to the left compared to participants without intellectual disabilities (Figure 2). Such results might reflect small differences between groups with respect to training intensity or, alternatively, might be based on differences in peak heart rates between groups as shown by Hilgenkamp and Baynard (2017). Although the group differences with respect to the intensity zones (Figure 2) were marginal and not significant, it was decided to normalize heart rate to peak heart rate, in order to consider possible physiological differences on the individual level. More accurate results might be achieved by measuring peak heart rate instead of calculating it. This would require medical examination and testing with a standardized protocol.

It was not possible to standardize the intensity distributions over time for players with and without intellectual disabilities. In soccer training, each player decides for himself with which intensity he participates in an exercise. Group differences also occurred regarding the training contents (Table 1). However, we do not think that these differences confounded our results: Fanchini et al. (2015) compared RPE of different intensity distributions in soccer training and concluded that the intensity distribution over time has no meaningful impact on RPE. Furthermore, we controlled time effects by using $time_{RPE}$ as covariate, and the semi-partial correlations between $time_{RPE}$ and RPE did not differ between groups.

The present study did not differentiate between the perception of exertion and the perception of effort. The instructions were provided in German and contained the word 'Anstrengung', which is the translation for both terms. Abbis et al. (2015) associated the perception of effort with the amount of mental and physical energy currently being given to a task that is influenced by the efference copy of the motor commands (corollary discharge hypothesis), and the perception of exertion with the sensations of strain experienced during the physical task (afferent feedback hypothesis). Future studies might differentiate between these perceptions and investigate whether people with intellectual disabilities have lower competencies with regard to feedforward prediction according to the corollary discharge hypothesis or the sensing of strain or fatigue.

5 | CONCLUSIONS

The present study observed impaired RPE in people with intellectual disabilities, which was partially explained by cognitive competencies related to processing speed and cognitive executive control. The results might sensitize coaches, teachers and peers of inclusive sports teams for impairments in the perception of exertion and possible causes in people with intellectual disabilities. Further research is needed to elucidate how perception of exertion can be improved in order to promote perceptually regulation of exercise intensity and to increase engagement in physical activities, which is a major goal of Article 30 of the UN Convention on the Rights of Persons with Disabilities (UN, 2006). Recent research reported acute effects of moderate and intensive exercise on processing speed and executive functions in people with (Chen & Ringenbach, 2016) and without intellectual disabilities (Chang & Etnier, 2008). As RPE seems to be related to these functions, future studies might investigate whether exercise also has acute effects on the competence for RPE and how training can be designed to achieve persistent effects.

ACKNOWLEDGMENTS

The study has not been funded. The authors thank all athletes for their participation. A special thanks to L. Walden, D. Thale, T. Schlump and E. Landwehr for their support in data collection. The authors further acknowledge assistance in recruiting participants by the representatives of the participating sheltered workshops and soccer clubs.

CONFLICT OF INTEREST

All authors declare that they have no competing interests. The submitted work was carried out in the absence of any personal, professional or financial relationships that could potentially be construed as a conflict of interest.

ORCID

Gerd Schmitz https://orcid.org/0000-0001-7819-2135

Sabine Schmitz https://orcid.org/0000-0002-6174-7322

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Schmitz G, Meis JM, Hafferkamp M, Schmitz S. Competencies for rating perceived exertion in amateur soccer players with and without intellectual disabilities. *J Appl Res Intellect Disabil*. 2019;00:1–10. https://doi.org/10.1111/jar.12668