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Psychometric properties of the French athlete version of the Coach-Athlete Relationship Questionnaire (Fr-CART-Q)

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Abstract:

Two studies were conducted to examine the psychometric properties of the French athlete version of the Coach-Athlete Relationship Questionnaire (Fr-CART-Q) among two independent samples of French athletes. Study 1 evaluated the reliability, factorial structure, and convergent, discriminant, and criterion validities of this scale among 442 French athletes (65.8% men; Mage = 21.66, SD = 4.82) involved in various sports. Study 2 investigated the same psychometric properties, as well as temporal invariance, among a specific sample of 286 adolescent handball players (58.4% men; Mage = 15.39 years, SD = 1.01) involved in intensive training centers. Both studies reveal that the psychometric properties of the Fr-CART-Q are satisfactory. Reliability indices and factorial structures confirm the multidimensional and hierarchical structure of the Fr-CART-Q. Temporal invariance analysis reveals that the factorial structure of this scale remains consistent over time. Criterion validity is satisfactory and the quality of the coach-athlete relationship is positively associated with athletes' perceived competence. Overall, these two studies indicate that the Fr-CART-Q can be used with French athletes.

Keywords: Interpersonal relationships; questionnaire validation; 3+1Cs model.

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For several decades, the sport psychology literature has been suggesting that the interpersonal processes involved in the relationship between coach and athlete(s) in a competitive sporting context need to be considered in order to achieve a better understanding of this singular relationship (Jowett & Cockerill, 2003). On this point, the 3+1Cs model (Jowett, 2007) is the theoretical framework that has been the most widely used in recent years to explore the affective, cognitive, and behavioral processes involved in the coach-athlete relationship (CAR) (for reviews, see McShan & Moore, 2023; Roux & Trouilloud, 2021). In its essence, the 3+1Cs model postulates that the quality of the CAR may be operationalized through the dimensions of closeness, commitment, complementarity, and co-orientation (Jowett, 2007, 2025). Closeness refers to the affective dimension of the CAR and reflects the mutual feelings of respect, confidence, and appreciation between coach and athletes. Commitment corresponds to the cognitive aspect of the relationship and represents the long-term intentions of both coach and athletes to maintain their relationship over time to achieve common goals. Complementarity can be considered as the behavioral dimension of the CAR and reflects the degree to which the coach and the athletes share roles and responsibilities and cooperate to achieve their goals. Finally, co-orientation refers to the degree of mutual understanding, expressed in the degree of concordance between athletes' and coaches' perceptions of the dimensions of closeness, commitment, and complementarity. Studies on the 3+1Cs model from the last twenty years reveal that the quality of the CAR may be considered as a key element in athletes' development, well-being, and performance (Jowett, 2025).

Considering these elements, the development of a psychometric scale to measure the quality of the CAR has emerged as an important issue in the field of sport psychology and coaching (Jowett & Poczwardowski, 2007). Based on the initial conceptualization studies of the 3+1Cs model, Jowett and Ntoumanis (2004) developed the Coach-Athlete Relationship Questionnaire (CART-Q). This 11-item English-language scale measures athletes' perceptions

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of the levels of closeness, commitment, and complementarity with their coach. Exploratory and confirmatory factor analyses revealed that the CART-Q has a three-dimensional factorial structure and that the reliability of these dimensions is satisfactory. Furthermore, confirmatory factor analyses indicated that a hierarchical model is also a suitable fit for the CART-Q, suggesting that the three dimensions could be nested under a higher-order factor that corresponds to the overall quality of the CAR. Finally, Jowett and Ntoumanis (2004) also provided empirical evidence regarding the criterion validity of the CART-Q, concluding that the different dimensions were related to athletes' satisfaction with the CAR.

Over the past twenty years, numerous studies have confirmed the psychometric validity of the CART-Q among various samples of athletes (e.g., Jowett et al., 2012) and coaches (e.g., Balduck & Jowett, 2010), as well as in different contexts, including individual and team sports (e.g., Roberto De Andrade Do Nascimento Junior et al., 2024). These studies provide evidence for the applicability and robustness of the CART-Q. Additionally, some studies have evaluated the psychometric properties of the CART-Q in various languages. To our knowledge, the CART-Q has been validated in 15 languages: Arabic (Ahmad et al., 2021; Jelleli et al., 2023), Brazilian (Contreira et al., 2019; Roberto De Andrade Do Nascimento Junior et al., 2024; Vieira et al., 2015), Chinese (Yang & Jowett, 2012), Braille (Sahin et al., 2020), Dutch (Balduck & Jowett, 2010; Balduck et al., 2011), Greek (Jowett & Ntoumanis, 2003), Hungarian (Kovács et al., 2021), Korean (Kim & Park, 2008), Malay (Kuan et al., 2024), Polish (Michalak & Poczwardowski, 2015), Portuguese (Pinho et al., 2024), Persian (Balzadeh et al., 2019), Spanish (Sanz-Fernández et al., 2023), Swedish (Yang & Jowett, 2012), and Turkish (Altıntaş et al., 2012). These cross-language validation studies have demonstrated that the psychometric properties of the CART-Q are satisfactory, and that the CART-Q is a suitable instrument for exploring the CAR through the lens of the 3+1Cs model in different languages and cultures. However, the analysis of the literature reveals that there has been no in-depth validation study of a French version of the CART-Q. Indeed, although some studies have used a French version of this scale (Combeau & Debanne, 2020; Isoard-Gauthier et al., 2016; Jowett et al., 2017; Roux et al., 2023), none of them have focused on evaluating the psychometric characteristics. Most of them (i.e., Combeau & Debanne, 2020; Isoard-Gauthier et al., 2016; Roux et al., 2023) were limited to only assessing the scale's reliability (i.e., internal consistency). While other psychometric characteristics (i.e., factorial structure and convergent and discriminant validities) were explored in one study (Jowett et al., 2017) among a sample of French athletes who were competing at relatively low levels (82% of the athletes competed at local and regional levels), the validity of this scale for specific samples of French athletes, such as those involved in

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intensive training contexts, remains unknown. Furthermore, despite the dynamic nature of the CAR (Roux et al., 2023), most previous studies used a cross-sectional design, which precluded the exploration of the temporal invariance of the French version of the CART-Q. While many authors emphasize the importance of investigating temporal invariance as part of the psychometric validation process (e.g., Flake et al., 2017; Milfont & Fischer, 2010), only one study (i.e., Vieira et al., 2015) has explored this property of the CART-Q. In their study, Vieira et al. (2015) evaluated the test-retest reliability of the CART-Q among a sub-sample of 50 athletes using an interval of seven days between tests, but this method is not robust enough to evaluate the temporal stability of the scale's factorial structure (DeSimone, 2015). The lack of knowledge regarding the temporal invariance of the CART-Q is one of the important limitations identified in the literature, and further investigation of this psychometric characteristic is warranted (e.g., Yang & Jowett, 2013).

On the basis of the elements presented above, two studies were conducted with the main goal of extending the cross-language validation of the CART-Q by exploring the psychometric properties (i.e., reliability, factorial validity, convergent validity, discriminant validity, criterion validity, temporal invariance) of a French-language athlete version of the CART-Q (Fr-CART-Q). Following scientific recommendations regarding the validation process in social psychology (e.g., Flake et al., 2017; Vallerand, 1989), two studies were carried out among two independent samples of athletes involved in different sporting contexts. Study 1 was conducted with a sample ($N = 442$) of French athletes practicing various sports at different levels. Study 2 was conducted with a specific sample of adolescent athletes ($N = 286$) involved in intensive handball training centers. These two studies explore the different psychometric properties of the Fr-CART-Q.

Firstly, these two studies aim to evaluate the reliability, factorial structure, and the convergent-discriminant validity of the CART-Q among French athletes. Additionally, they explore the criterion validity of the Fr-CART-Q by examining the associations of CAR quality with athletes' self-perceptions of competence. On this point, several studies have reported a positive association between the CAR quality and athletes' self-perceptions of competence (e.g., Jackson et al., 2010; Jowett, 2008; Stephen et al., 2022), particularly through the high expectations and supportive behaviors of coaches in high-quality relationships (Jowett & Cramer, 2010; Sarrazin et al., 2005). On the basis of these findings, athletes' self-perceptions of sport competence were selected as the criterion variable, and it was hypothesized that the CAR quality would be positively associated with these perceptions. Finally, Study 2 adopts a

longitudinal design to examine the temporal invariance of the Fr-CART-Q over a three-month period.

Study 1

Method

Elaboration of a French version of the CART-Q

The committee method (e.g., Vallerand, 1989) was used to develop a preliminary version of the Fr-CART-Q. Specifically, three researchers with expertise in social psychology and sport psychology independently translated the original 11 items from Jowett & Ntoumanis (2004). The different translations were then compared with each other and with the French version used in the study of Jowett et al. (2017). The synthesis of these translations resulted in a preliminary version of the 11 Fr-CART-Q items. A pre-test was then conducted with 15 athletes ($M = 19.29$, $SD = .73$) practicing various sports in order to assess the degree of clarity of the translated items. Each participant was asked to read the items and rate their clarity on a scale from 1 to 7. Items with an average score of above five were considered sufficiently clear (Vallerand, 1989). As all items obtained clarity scores of above 5.93, they were retained for the present study.

Participants and procedure

The sample consisted of 442 French athletes (men comprise 65.8% of the sample) between 15 to 53 years old ($M = 21.66$, $SD = 4.82$). Of these, 264 (59.7%) practiced a team sport (e.g., soccer, handball, rugby) and 178 (40.3%) practiced an individual sport (e.g., rowing, tennis, athletics). These athletes competed at local (39.4%), regional (42.1%), national (19.7%), and international (3.8%) levels. On average, they had been practicing their sport for 10.42 years ($SD = 6.24$), and the duration of the relationship with their current coach ranges from 6 months to 14 years ($M = 2.48$; $SD = 2.38$). They trained on average 2.76 times per week ($SD = 1.31$), representing 6.71 hours of practice per week ($SD = 4.79$). An informed consent form was distributed to all participants. Institutional ethical approval was obtained from the Ethics Committee for Non-Interventional Studies of both authors' university (Ethics approval number: 2013-05-07-16).

Measures

Quality of the CAR. Athletes completed the Fr-CART-Q to evaluate their perceptions of closeness (four items; e.g., “I respect my coach”), commitment (three items; e.g., “I feel committed to my coach”), and complementarity (four items; e.g., “When I am coached by my

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coach, I am ready to do my best”) with their coach (Jowett & Ntoumanis, 2004). Responses were collected using a Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Self-perceptions of competence. Athletes’ self-perceptions of their competence in their sport were measured via three items (e.g., “I feel competent in my sport”; Trouilloud & Amiel, 2011). Responses were collected using a Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). The reliability of this scale was satisfactory ($\alpha = .70$; $\omega = .71$). The mean of the responses was thus calculated and considered as an indication of athletes’ self-perceptions of competence.

Data analysis

The data were analyzed using a four-step approach. Firstly, the reliability of the Fr-CART-Q was explored using Cronbach’s (1951) alpha (α) and McDonald’s (1999) omega (ω) coefficients. Values above .70 were considered as satisfactory (Nunnally & Bernstein, 1994).

Secondly, confirmatory factor analyses (CFA) were conducted to test the factorial structure of the Fr-CART-Q. On the basis of previous CART-Q validation studies (e.g., Balduck et al., 2011; Jowett & Ntoumanis, 2004), a preliminary model (M1) corresponding to a three-factor model (i.e., closeness, commitment, and complementarity) was evaluated. A second-order model (M2) was then tested to determine whether the three first-order factors define a broader construct representing the overall quality of the CAR (Jowett & Ntoumanis, 2004). Following Bonett et al. (2002), Mardia’s coefficients (i.e., Mardia skewness and Mardia kurtosis) were calculated and revealed that the multivariate normality of the data was not respected (Mardia skewness = 1394.83, $p < .001$; Mardia kurtosis = 21.94, $p < .001$). On this point, recent studies on CFA have suggested that diagonally weighted least squares (DWLS) estimation is a more appropriate approach for analyzing latent concepts estimated by ordinal Likert-type items and for dealing with the resulting potential multivariate non-normality problems (DiStefano & Morgan, 2014; Li, 2016). Thus, the DWLS estimator was used to conduct CFA analyses. Several fit indices were selected to assess the factorial structure of the tested models: the chi-square ratio (χ^2/df), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR) (see Hair et al., 2009 for a detailed presentation). A χ^2/df of less than 5, CFI and TLI values of more than .90, a RMSEA value of less than .05, and an SRMR value of less than .08 indicate a good fit for the tested model (e.g., Hair et al., 2009). These values also enable the comparison of different models: the model with the best fit indices can be considered as the one that best fits the data.

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Thirdly, CFA were also used to explore the convergent and discriminant validities of the Fr-CART-Q. Convergent validity was explored through average variance extracted (AVE). Factor loadings that were above .50 and significant ($p < .05$) were considered to be satisfactory (Hair et al., 2009). Discriminant validity was evaluated through inter-factor correlations. Values below .80 were considered satisfactory (Rönkkö & Cho, 2022) because they indicate that these dimensions are sufficiently independent of each other (Li & Harmer, 1996).

Finally, structural equation modeling (SEM) was conducted to explore the criterion validity of the Fr-CART-Q in relation to athletes' self-perceptions of competence; SEM can be considered as an extension of CFA, using the same indices to assess fit (Zumbo, 2005). Specifically, the three items measuring athletes' self-perceptions of competence were incorporated into the factorial model, and SEM was used to evaluate the criterion validity of the Fr-CART-Q.

Analyses were carried out with Rstudio 4.1.0 (R Core Team, 2021) using the lavaan package (Rosseel, 2012).

Results

Descriptive statistics

First, the Mahalanobis D^2 distance (Hair et al., 2009) was used to identify potential multivariate outliers in the sample. Twenty-two multivariate outliers were identified (i.e., D^2 values exceeding the critical value of $\chi^2(3) = 16.27, p < .001$ for commitment and $\chi^2(4) = 18.47, p < .001$ for closeness and complementarity) and were removed from the analysis. Table 1 presents the descriptive statistics for the 11 items of the Fr-CART-Q for the final sample of 420 athletes.

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Table 1. Translation and descriptive statistics of the 11 items of the Fr-CART-Q.

<i>Original version (Jowett & Ntoumanis, 2004)</i>	<i>French version</i>	α	ω	<i>M</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>
<i>Closeness</i>	<i>Proximité</i>	0.87	0.88				
1. I like my coach	1. J'apprécie mon entraîneur			5.82	1.26	-1.16	1.30
2. I feel appreciation for the sacrifices my athlete/coach has experienced in order to improve his/her performance	2. J'apprécie les sacrifices faits par mon entraîneur			5.26	1.56	-0.78	0.02
3. I respect my coach	3. J'éprouve du respect pour mon entraîneur			6.44	0.92	-1.77	2.64
4. I trust my coach	4. J'ai confiance en mon entraîneur			5.73	1.41	-1.19	1.15
<i>Commitment</i>	<i>Engagement</i>	0.64	0.65				
5. I feel close to my coach	5. Je me sens proche de mon entraîneur			5.02	1.65	-0.74	-0.09
6. I feel committed to my coach	6. Je me sens lié(e) à mon entraîneur			5.28	1.59	-1.05	0.62
7. I feel that my sport career is promising with my coach	7. J'ai le sentiment que mon avenir sportif est étroitement lié à mon entraîneur			3.77	1.89	-0.01	-1.11
<i>Complementarity</i>	<i>Complémentarité</i>	0.80	0.80				
8. When I am coached by my coach, I feel at ease	8. Quand je suis avec mon entraîneur, je me sens à l'aise			5.92	1.28	-1.40	1.84
9. When I am coached by my coach, I am ready to do my best	9. Quand je suis avec mon entraîneur, je suis prêt à donner le meilleur de moi-même			5.08	1.61	-0.69	-0.18
10. When I am coached by my coach, I adopt a friendly stance	10. Quand je suis avec mon entraîneur, j'adopte une attitude amicale			5.96	1.24	-1.54	2.56
11. When I am coached by my coach, I feel responsive to his/her effort	11. J'apprécie les efforts faits par mon entraîneur			5.72	1.21	-0.88	0.57

Note. α = Cronbach's alpha; ω = McDonald's omega.

Reliability

The reliability indices were very satisfactory for closeness ($\alpha = .87$; $\omega = .88$) and complementarity ($\alpha = .80$; $\omega = .80$) and relatively satisfactory for commitment ($\alpha = .64$; $\omega = .65$).

Factorial structure

The fit indices of the first- and second-order models are presented in Table 2.

Table 2. Fit indices of the structural models tested.

Model	χ^2	df	<i>p</i>	χ^2/df	RMSEA (90% CI)	SRMR	CFI	TLI
M1	64.699	41	.011	1.58	.037 (.018-.054)	.059	.993	.991
M2	67.883	41	.005	1.66	.040 (.022-.056)	.060	.992	.989

Note. χ^2 = Chi-square; df = degree of freedom; χ^2/df = Chi-square ratio; RMSEA = Root Mean Square Error of Approximation; CI = Confidence interval; SRMR = Standardized Root Mean Square Residual; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; M1 = first-order model; M2 = second-order model.

Results reveal a very good fit for the first-order model (M1; $\chi^2/df = 1.58$, $p < .05$; RMSEA = .04; SRMR = .06; CFI = .99; TLI = .99). Based on previous studies suggesting the existence of a second-order model (e.g., Balduck et al., 2011; Jowett & Ntoumanis, 2004), another CFA was conducted. This also revealed a very good fit for the second-order model ($\chi^2/df = 1.66$, $p < .005$; RMSEA = .04; SRMR = .06; CFI = .99; TLI = .99), with fit indices very similar to those of the first-order model. According to Marsh (1987), the validity of the second-order model can be established if its fit is identical to, or very similar, to that of the first-order model. Therefore, the second-order model M2, which involves a factor representing the overall quality of the CAR, can also be considered as satisfactory.

Convergent and discriminant validities

Concerning convergent validity, the analysis of the AVE reveals that the loadings of almost all items to their respective factors are satisfactory ($AVE > .68$, $p < .001$) (see Figure 1). Only one commitment item (“I feel that my sport career is promising with my coach”) has a lower factor loading ($AVE = .37$). In view of these elements, the convergent validity of the second-order model can be considered as satisfactory.

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Concerning discriminant validity, the results reveal very high inter-factor correlations between closeness, commitment, and complementarity ($r_s > .90$). These findings suggest that these three dimensions are not independent (Rönkkö & Cho, 2022) and emphasize the relevance of investigating the validity of a second-order model.

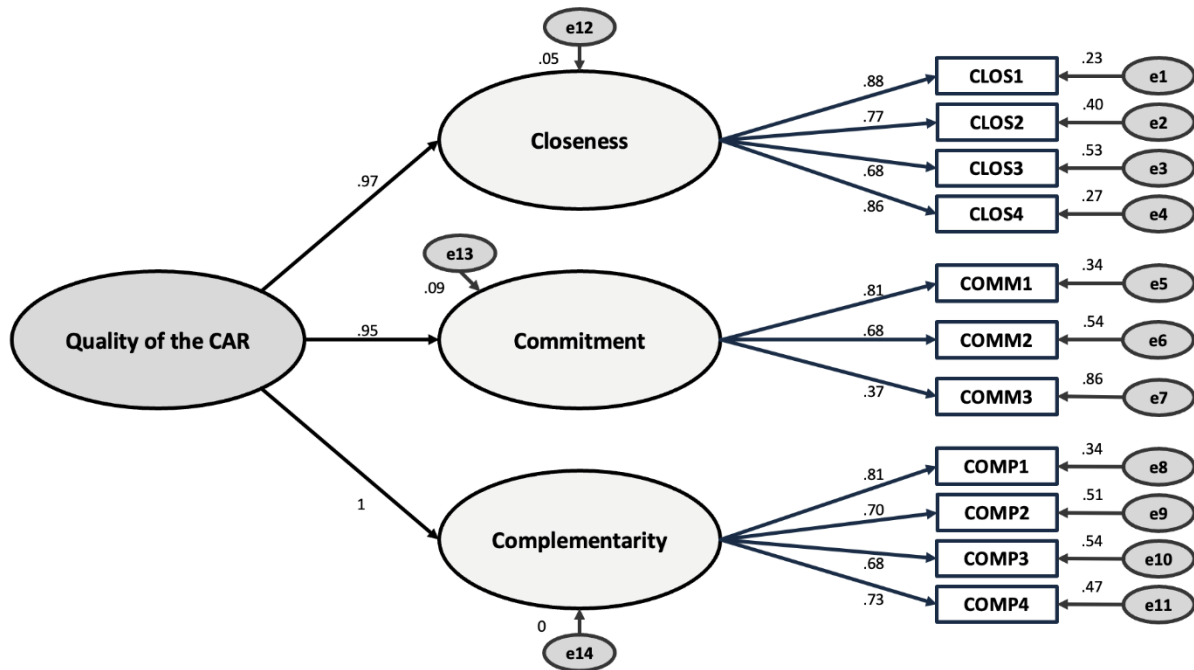


Figure 1. Factorial structure of the second-order model of the 11-item Fr-CART-Q.
Note. CLOS = Closeness; COMM = Commitment; COMP = Complementarity.

Criterion validity

The results of the SEM (see the first figure in supplementary material) indicate a good fit for the tested model M2 ($\chi^2/df = 1.21, p < .001$; RMSEA = .02; SRMR = .05; CFI = .99; TLI = .99), as well as satisfactory factor loadings for the three items measuring athletes' self-perceptions of competence (AVE > .62). Additionally, results indicate that the overall quality of the CAR is positively associated with athletes' self-perceptions of competence ($\beta = .30, p < .001$).

Discussion

This first study examined some psychometric properties (i.e., reliability, factorial structure, and the convergent, discriminant, and criterion validities) of a French version of the CART-Q with a sample of 420 athletes. Overall, the results support the validity of this scale.

First, the results indicate that the Fr-CART-Q has good reliability, with very good internal consistency for closeness and complementarity and satisfactory internal consistency

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for commitment. These findings are consistent with those of previous studies (e.g., Pinho et al., 2024).

Secondly, CFA reveal a good factorial structure for the Fr-CART-Q. Results indicate that the quality of the CAR could be satisfactorily described by both a first-order model with three dimensions (i.e., closeness, commitment, and complementarity) and by a second-order model with a higher-order factor representing the overall quality of the CAR. The convergent validity of the Fr-CART-Q is also satisfactory. These results are in line with those reported in previous studies (e.g., Balduck & Jowett, 2010; Jowett & Ntoumanis, 2004). However, the discriminant validity of the measurement model appear unsatisfactory, suggesting that the dimensions of closeness, commitment, and complementarity are not completely independent of each other. These findings corroborate the existing literature on the psychometric properties of the CART-Q (e.g., Woolliams et al., 2021) and emphasize the importance of considering a second-order model that incorporates an overall CAR quality factor (Balduck et al., 2011).

Finally, results reveal a positive association between the CAR quality and athletes' self-perceptions of competence. This finding is consistent with those reported by previous studies (e.g., Jackson et al., 2010; Stephen et al., 2022) and supports the criterion validity of the Fr-CART-Q.

Although this study highlights the psychometric validity of the Fr-CART-Q, it also brings attention to the scale's limitations, specifically with respect to the commitment dimension. Indeed, the reliability indices for commitment are lower than those for closeness and complementarity, which is a finding that has been highlighted by some previous studies (e.g., Vieira et al., 2015). One possible explanation is that commitment is represented by only three items while closeness and complementarity are each represented by four items (Nunnally & Bernstein, 1994). Additionally, convergent validity analyses also reveal a rather low factor loading for one commitment item (i.e., "I feel that my sport career is promising with my coach"). This may be at least in part caused by the fact that this study primarily involved athletes who were mostly practicing at the local or regional level. In this context of practice, it could be hypothesized that athletes do not perceived that their sport career is closely linked with their coach. In view of these elements, it seems important to evaluate the psychometric properties of the Fr-CART-Q among athletes with different characteristics, notably in terms of level (e.g., national) and frequency of practice (e.g., intensive practice). Finally, from a conceptual point of view of the 3+1C theoretical framework, the content of the commitment items seems to be relatively limited. Indeed, commitment has been defined by Jowett (2007) as the development of a shared framework of reference between coach and athlete, reflecting the degree of mutual

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attachment and the intention to maintain the relationship over time in order to achieve common goals. However, although the original version of the CART-Q comprises three items that explore the nature of commitment between coach and athlete (e.g., “I feel committed to my coach”) and their long-term orientation (e.g., “I feel that my sport career is promising with my coach”), the notion of common goals does not appear to be explicitly explored. Yet this notion is considered to be central in defining the dimension of commitment (e.g., Jowett & Clark-Carter, 2006). Consequently, a fourth item exploring the concept of shared goals between coach and athlete was developed in Study 2 in order to provide a more accurate assessment of the commitment dimension.

Study 2

Building on the findings of Study 1, the second study aims to confirm the psychometric properties of the Fr-CART-Q (in terms of reliability, factorial structure, and convergent, discriminant, and criterion validities). A fourth item has been added to the commitment dimension and the study was conducted with a sample of adolescent handball players involved in intensive training centers. Furthermore, this study adopted a longitudinal design in order to examine the temporal invariance of the Fr-CART-Q.

Method

Development of a new item for the commitment dimension

Two experts in sport psychology independently developed a new item corresponding to the shared goals and mutual dedication between athlete and coach (Jowett, 2007). After comparing their proposals, the item “I feel that this coach and I are mutually committed to common goals” was retained (see Table 3).

Participants and procedure

Two hundred and eighty-six adolescent male (58.4%) and female (41.6%) handball players involved in intensive training centers participated in this study. They were on average 15.39 years old ($SD = 1.01$) and practiced at national (50.7%) and regional (49.3%) levels. These athletes trained on average 3.78 times per week ($SD = 1.33$), representing about 7.35 hours of practice ($SD = 2.92$). The managers of the training centers were first contacted to obtain their approval for this study, and an informed consent form was administered to all athletes and their parents. Institutional ethical approval was obtained from the Ethics Committee for Non-Interventional Studies of both authors' university (Ethics approval number: IRB00010290-2018-10-16-53 CER Grenoble Alpes).

Measures

Quality of the CAR. Athletes completed the 12-item revised version of the Fr-CART-Q to evaluate their perceptions of closeness (four items), commitment (four items), and complementarity (four items). Their responses were collected using a Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Self-perceptions of competence. Athletes' self-perceptions of their competence in handball were measured using three items (e.g., “I feel competent in handball”) (see Study 1). Responses were collected using a Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). The internal consistency of these items was satisfactory ($\alpha = .78$; $\omega = .79$).

Data analysis

The data analysis strategy of Study 1 was used to evaluate the reliability, factorial structure, and the convergent, discriminant, and criterion validities of the revised 12-item Fr-CART-Q. As Mardia's coefficients (Bonett et al., 2002) reveal multivariate non-normality of the data (Mardia skewness = 1049.67, $p < .001$; Mardia kurtosis = 16.68, $p < .001$) the DWLS estimator was used to conduct CFA (DiStefano & Morgan, 2014).

Moreover, the temporal invariance of the Fr-CART-Q was tested among a subset of athletes ($N = 218$) of the full sample. These athletes completed the questionnaire twice: at the beginning (i.e., October) and middle (i.e., January) of the season. The data were analyzed using confirmatory multiple-group factor analyses (Hirschfeld & Brachel, 2014), which test models with increasing levels of constraints and measure their differences. Following the recommendations of Milfont & Fischer (2010), five models were tested. In the structural invariance model (Model A), the factorial structure is constrained to be identical for the two measurements. In the metric invariance model (Model B), the factor loadings of the items are constrained to be identical. In the scalar invariance model (Model C), the constants of the items are constrained to be identical. The scalar bis invariance model (Model D) forces the means of the items to be identical for the two measurement times. In the strict invariance model (Model E), the residual errors of the items are constrained to be identical for both measurements. A χ^2 difference test (i.e., Likelihood Ratio Test) was used to compare these models. A non-significant χ^2 test result ($p > .05$) and a CFI delta below .01 indicate that the constrained model explains the phenomenon as well as the unconstrained model, and therefore that the type of invariance being tested can be considered as satisfactory (Hirschfeld & Brachel, 2014). All these analyses were performed with Rstudio 4.1.0 (R Core Team, 2021) using the lavaan package (Rosseel, 2012).

Results

Descriptive statistics

First, Mahalanobis distances were calculated (Hair et al., 2009) and six multivariate outliers were identified: athletes with a distance greater than the critical value of $\chi^2(4) = 18.47$, $p < .001$ for each of the three dimensions were removed from the sample. The final sample for this study consists of 280 athletes.

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Table 3. Descriptive statistics.

Items	α	ω	<i>M</i>	<i>SD</i>	Skewness	Kurtosis
<i>Closeness</i>	0.83	0.84				
CLOS1. J'apprécie mon entraîneur			5.30	1.46	-0.74	0.10
CLOS2. J'apprécie les sacrifices faits par mon entraîneur			5.16	1.35	-0.47	-0.34
CLOS3. J'éprouve du respect pour mon entraîneur			6.29	1.05	-1.65	2.44
CLOS4. J'ai confiance en mon entraîneur			5.61	1.35	-0.80	0.07
<i>Commitment</i>	0.76	0.77				
COMM1. Je me sens proche de mon entraîneur			4.01	1.55	-0.11	-0.43
COMM2. Je me sens lié à mon entraîneur			4.26	1.71	-0.19	-0.77
COMM3. J'ai le sentiment que mon avenir sportif est étroitement lié à mon entraîneur			4.60	1.51	-0.53	-0.14
COMM4. Je sens que mon entraîneur et moi-même sommes mutuellement engagés vers des buts communs			5.09	1.33	-0.59	0.20
<i>Complementarity</i>	0.73	0.74				
COMP1. Quand je suis avec mon entraîneur, je me sens à l'aise			4.91	1.55	-0.55	-0.39
COMP2. Quand je suis avec mon entraîneur je suis prêt à donner le meilleur de moi-même			5.65	1.32	-0.92	0.46
COMP3. Quand je suis avec mon entraîneur j'adopte une attitude amicale			3.87	1.77	0.003	-0.87
COMP4. J'apprécie les efforts faits par mon entraîneur			5.31	1.35	-0.48	-0.44

Note. CLOS = Closeness; COMM = Commitment; COMP = Complementarity; α = Cronbach's alpha; ω = McDonald's omega.

Reliability

The indices of reliability were satisfactory for closeness ($\alpha = .83$; $\omega = .84$), commitment ($\alpha = .76$; $\omega = .77$), and complementarity ($\alpha = .73$; $\omega = .74$).

Factorial structure

Results of the CFA and the fit indices of the first- and second-order models are presented in Table 4.

Table 4. Fit indices of the structural models tested.

Model	χ^2	df	<i>p</i>	χ^2/df	RMSEA (90% CI)	SRMR	CFI	TLI
M1	99.730	51	.000	1.96	.059 (.041-.075)	.072	.986	.982
M2	101.556	51	.000	1.99	.060 (.042-.076)	.073	.985	.981

Note. χ^2 = Chi-square; df = degree of freedom; χ^2/df = Chi-square ratio; RMSEA = Root Mean Square Error of Approximation; CI = Confidence interval; SRMR = Standardized Root Mean Square Residual; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; M1 = first-order model; M2 = second-order model.

Results of the CFA reveal a very good fit of the first-order model (M1; $\chi^2/df = 1.96$, $p < .001$; RMSEA = .06; SRMR = .07; CFI = .99; TLI = .98). Moreover, results of the CFA indicate that the second-order model also has a very good adjustment, with similar fit indices to those of the M1 model (M2; $\chi^2/df = 1.99$, $p < .005$; RMSEA = .06; SRMR = .07; CFI = .99;

TLI = .98). Following Marsh's (1987) recommendations, the second-order model was retained for further analyses.

Convergent and discriminant validities

Concerning the convergent validity of the model, results reveal that the factor loadings are satisfactory for all items ($AVE > .45, p < .001$) (see Figure 2). Furthermore, the results of the second-order model indicate that the factor loadings of closeness, commitment, and complementarity to the overall quality of the CAR are also satisfactory ($AVE > .93$) (see Figure 2).

Regarding the discriminant validity of the model, the results indicate high inter-factor correlations between the dimensions of closeness, commitment, and complementarity ($r_s > .89$). This suggests that these three dimensions are not independent (Rönkkö & Cho, 2022), emphasizing the relevance of considering a second-order model.

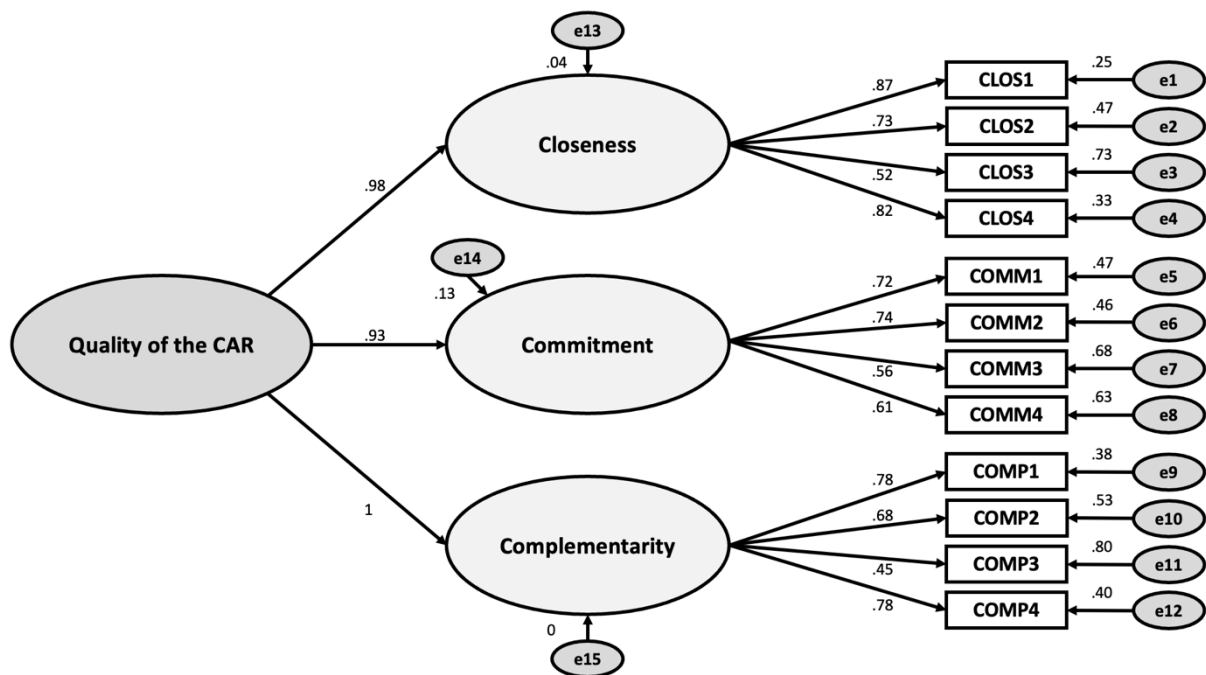


Figure 2. Factorial structure of the second-order model of the 12-item Fr-CART-Q.
 Note. CLOS = Closeness; COMM = Commitment; COMP = Complementarity.

Temporal invariance

The fit indices and chi-square test results of the five models used to evaluate the temporal invariance of the Fr-CART-Q are presented in Table 5. The χ^2 difference tests indicate that structural invariance (model A), metric invariance (model B), both types of scalar invariance (models C and D), and strict invariance are satisfied (χ^2 test significance $> .05$; $\Delta CFI < .01$), with the corresponding parameter values meeting the threshold values

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recommended in the literature (Hirschfeld & Von Brachel, 2014). This means that the factorial structure, the factor loadings, the constants, the means, and the residual errors of the 12 items, as well as the 3 factors of the Fr-CART-Q do not differ between the first and the second measurement (Dimitrov, 2010). These results therefore indicate strict invariance of the Fr-CART-Q over time.

Table 5. Fit indices and results of chi-square comparison tests of the different invariance models.

Model	χ^2	df	χ^2/df	RMSEA (90% CI)	CFI	SRMR	ΔCFI	$\Delta \chi^2$	Δdf	<i>p</i>
Model A	180.743	103	1.75	.059 (.044-.073)	.986	.071				
Model B	199.644	114	1.75	.059 (.045-.072)	.985	.075	.001	18.90	11	.06
Model C	206.287	122	1.69	.056 (.043-.070)	.985	.076	.000	6.64	8	.58
Model D	206.785	126	1.64	.054 (.041-.067)	.986	.073	.001	.50	4	.97
Model E	216.940	138	1.57	.051 (.038-.064)	.986	.077	.000	10.16	12	.60

Note. Model A = Structural invariance model; Model B = Metric invariance model; Model C = Scalar invariance model; Model D = Scalar bis invariance model; Model E = Strict invariance model; χ^2 = Chi-square; df = degree of freedom; χ^2/df = Chi-square ratio; RMSEA = Root mean square error of approximation; CI = Confidence interval; CFI = Comparative Fit Index; SRMR = Standardized Root Mean Square Residual; ΔCFI = difference between CFI value of the present model and that of the previous model; $\Delta \chi^2$ = difference between χ^2 value of the present model and that of the previous model; Δdf = difference between degree of freedom of the present model and that of the previous model; *p* = p-value of the χ^2 test.

Criterion validity

The results of the SEM (see supplementary material two for the figure) reveal a satisfactory fit of the model tested ($\chi^2/df = 1.52$, $p < .001$; RMSEA = .04; SRMR = .07; CFI = .99; TLI = .99). The factor loadings of the three items of athletes' self-competence are satisfactory (AVE > .64, $p < .001$), suggesting that these items adequately converge towards their theoretical factor. Furthermore, the results indicate that the overall quality of the CAR is positively associated with athletes' perceptions of self-competence ($\beta = .41$, $p < .001$).

Discussion

The aim of this second study was to confirm the reliability, factorial structure, and the convergent, discriminant, and criterion validities of the Fr-CART-Q among a sample of 286 adolescent handball players involved in intensive training centers. Furthermore, the temporal invariance of this scale was examined by collecting data twice over a three-month period. Overall, the analyses reveal satisfactory results.

Firstly, the reliability analyses indicate that internal consistency for the closeness, commitment, and complementarity dimensions are very satisfactory; this is consistent with the findings of previous validation studies of the CART-Q (e.g., Balduck & Jowett, 2010).

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Moreover, the results reveal that the reliability of the commitment dimension in Study 2 is superior to that in Study 1. These findings suggest that adding a fourth item to assess the athletes' perceptions of common goals with their coach can be considered as a suitable approach to explore commitment in the CAR.

Secondly, factorial structure analyses provide support for both the first- and second-order models. These results corroborate previous findings (e.g., Jowett & Ntoumanis, 2004) suggesting that the CAR quality can be explored through the specific dimensions of closeness, commitment, and complementarity, as well as through an overall indicator including these three dimensions. Results also reveal that the factor loadings for each item are satisfactory, providing evidence for the convergent validity of the Fr-CART-Q. However, as noted in previous studies (e.g., Pinho et al., 2024), the high inter-factor correlations do not completely support the discriminant validity of the scale. These findings suggest that closeness, commitment, and complementarity must be considered as interdependent dimensions and highlight the relevance of the second-order model for examining the quality of the CAR.

Thirdly, the multi-group CFA reveal that the Fr-CART-Q has strict temporal invariance over a three-month period, indicating that the factorial structure of this scale remains stable between the two-measurement times. This result suggests that the Fr-CART-Q can be considered as a suitable scale for exploring the CAR quality from a dynamic perspective.

Finally, criterion validity analyses reveal a positive relationship between athletes' perceptions of CAR quality and their self-perceptions of competence in their sport. These findings support the external validity of the Fr-CART-Q and are line with Study 1 and previous research, indicating that CAR quality positively predicts athletes' physical self-concept (Jowett, 2008).

General discussion

These two studies examined the psychometric properties of a French version of the CART-Q in two independent samples of athletes. Overall, the results of both studies strongly support the validity of the Fr-CART-Q and suggest that this scale can be used to explore CAR quality with French athletes.

Firstly, satisfactory reliability scores were found for the dimensions of closeness, commitment, and complementarity in both studies. These findings are consistent with those reported by studies focused on the validation of the original scale (Jowett & Ntoumanis, 2004) and on cross-cultural adaptations of the scale (Balduck et al., 2011; Yang & Jowett, 2012).

Secondly, the results of both studies supported the multidimensional structure of the Fr-CART-Q, reflecting the interpersonal constructs of closeness, commitment and

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complementarity. These findings are aligned with the theoretical conceptualization of the CAR (Jowett, 2007). More precisely, the analysis of different measurement models through SEM indicated that both a three factors first-order model and a hierarchical factor model, in which the three first-order factors (closeness, commitment, and complementarity) were subsumed under a higher-factor (i.e., overall quality of the CAR), were acceptable. Moreover, results of both studies revealed dissatisfying discriminant validity of the model, suggesting that closeness, commitment, and complementarity should be considered as interdependent constructs. These findings corroborate most previous studies that have explored the psychometric properties of the CART-Q in different languages (e.g., Balduck et al., 2011; Contreira et al., 2019) and indicate that the CAR can be satisfactorily approached through the three dimensions of closeness, commitment, and complementarity nested within a more general factor representing the overall quality of the CAR (Woolliams et al., 2021). These elements suggest that a general measure of CAR quality (computed as the mean of the three CART-Q subscales) could be adopted by researchers and practitioners interested in an overall measure of CAR quality. However, those interested in exploring the relationships between specific CAR dimensions and other variables are likely to find it more useful to consider the three dimensions of CAR quality, as the three dimensions allow a more in-depth assessment of the construct.

However, it should be noted that the convergent validity of the Fr-CART-Q in Study 2 is superior to that in Study 1. Specifically, the factor loading of the commitment item “I feel that my sporting career is promising with my coach” is higher in Study 2. These findings may be linked to the characteristics associated with different practice levels, suggesting that this commitment item may be more relevant for elite athletes. Indeed, the athletes in Study 2 were involved in intensive handball training centers and those in Study 1 practiced their sport at a lower frequency. In contexts such as intensive training centers, the quality of the CAR may play a crucial role in athletes’ development and achievements, particularly given that the coach is the person with whom the athletes interact most (Sandström et al., 2016). Therefore, it could be hypothesized that the feeling that one’s career is linked to one’s coach is particularly important in this type of context.

Furthermore, Study 2 revealed that the Fr-CART-Q has strict temporal invariance over a three-month period. This result is an important contribution to the literature on the psychometric validity of the CART-Q, as the temporal invariance of this scale has not yet been robustly addressed (see Vieira et al., 2015, for a preliminary exploration of this issue). As athletes’ perceptions of the CAR quality are dynamic characteristics that are likely to evolve over time (Roux et al., 2023), exploring the temporal invariance of the CART-Q must be

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considered as a key element. The strict temporal invariance of the Fr-CART-Q highlighted in this study suggests that this scale may be suitable for longitudinal studies and repeated measurements designed to explore the dynamic of the CAR quality over time.

Finally, the external validity of the Fr-CART-Q was examined by assessing the ability of the CAR quality to predict athletes' self-perceptions of competence. The results were satisfactory in both studies and consistent with previous research on this topic (e.g., Jowett, 2008; Stephen et al., 2022), confirming that the athletes' perceptions of the CAR quality are positively associated with their self-perceptions of competence.

Limitations and perspectives

Although Studies 1 and 2 support the validity of the Fr-CART-Q and indicate that this scale can be reliably used to measure the quality of the CAR in French athletes, some limitations should be considered.

Firstly, the results suggest that the Fr-CART-Q is better suited to analyzing the CAR quality among athletes involved in intensive practice contexts. This suggests that athletes' perceptions of CAR quality may differ depending on the level of practice. On this point, Jowett & Nezelek (2012) indicated that interdependence is greater among athletes and coaches operating at higher competitive levels. They proposed that at these levels, coaches and athletes develop more interdependent relationships to manage the multiple risks associated with high-performance sport (e.g., injury, failure to qualify for a major competition). Similarly, Sanz-Fernández et al. (2023) reported that female athletes playing at a professional level felt closer to their coaches than other athletes did. Thus, it could be suggested that the structure of the CART-Q may be impacted by some individual and contextual characteristics. However, measurement invariance across groups has not been widely investigated by previous studies. To our knowledge, only four studies have examined CART-Q invariance in relation to athletes' nationality (Yang & Jowett, 2012), cultural background (Ada et al., 2021), gender, sport practiced, and age (Pinho et al., 2024; Roberto De Andrade Do Nascimento Junior et al., 2024). Further studies are needed to explore this line of research to examine the degree to which the psychometric properties of the Fr-CART-Q are equivalent across age, gender, sports, and levels of practice.

Secondly, as these two studies only examined athletes' direct perspective of the CAR quality, they do not provide a complete overview of the CAR. Indeed, the 3+1Cs model (Jowett, 2007) underlines the importance of exploring the meta-perspective (i.e., what one thinks the other member of the dyad perceives of the relationship in terms of closeness, commitment and complementarity; Jowett & Clark-Carter, 2006). Cross-assessing both athletes and coaches'

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direct and meta-perspectives would enable researchers and practitioners to examine the level of co-orientation within the CAR. Future studies are therefore encouraged to pursue this line of research, by exploring athletes' meta-perspective and coaches' versions of the Fr-CART-Q.

Disclosure of interest

No potential conflict of interest was reported by the authors.

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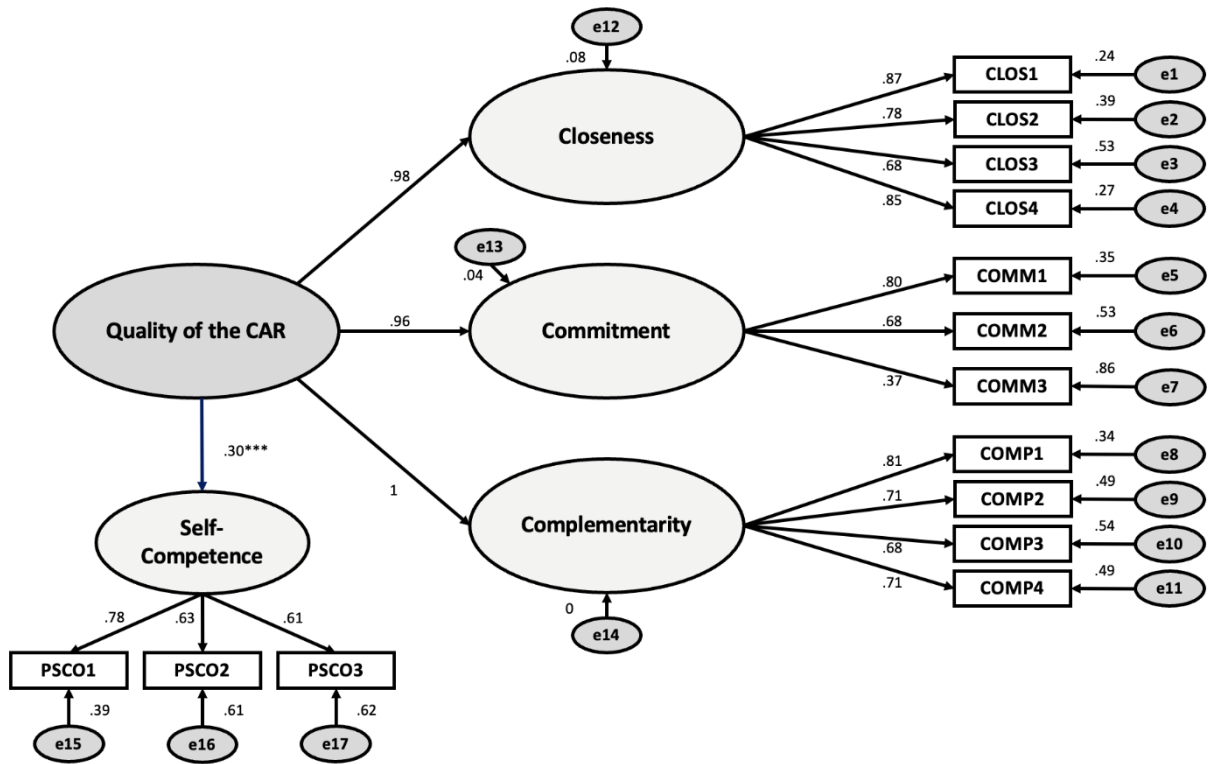
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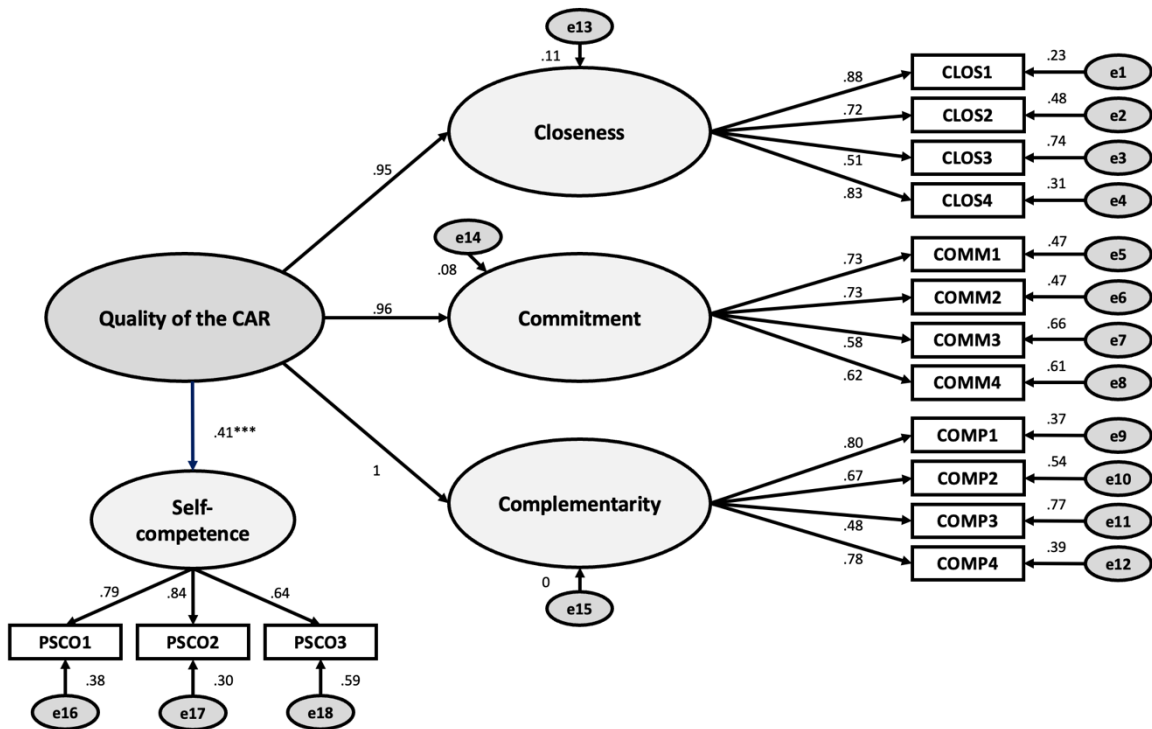
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Supplementary materials



Supplementary material 1. Factorial structure of the Structural Equation Modelling in Study 1. Note. CLOS = Closeness; COMM = Commitment; COMP = Complementarity; PSCO = Self-perceptions of competence



Supplementary material 2. Factorial structure of the Structural Equation Modelling in Study 2. Note. CLOS = Closeness; COMM = Commitment; COMP = Complementarity; PSCO = Self-perceptions of competence