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Testing a New Model of Team Interdependence

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ABSTRACT

Companies rely on teams to combine their different skills and solve multidisciplinary problems (Engestrom, 2008; Schrage, 1995). One crucial characteristic of teams is their interdependent nature (Sundstrom, de Meuse, & Futrell, 1990). However, interdependence as a construct is not well understood and its role in dynamic team processes is not clear. Recent theoretical advances have proposed a new model of interdependence – one that places two forms of interdependence at the beginning of a path that acts through task and social constructs to impact team effectiveness (Courtright, Thurgood, Stewart, & Pierotti, 2015). This new model was tested in two data sets of engineering student project teams. Evidence supported only one of four proposed pathways in one data set, and none of the pathways in the second data set. These findings suggest that either this model does not represent team dynamics well, or the samples on which the model was initially meta-analytically tested do not generalize to the present samples. Future research should continue to test this model in other samples, using other measures of interdependence, mediators, and outcome variables.

KEYWORDS: interdependence, collaboration, multilevel, work group, cohesion, performance, project team.

DEDICATION

To my family, Brian, Chris, Sebastian, Sofia, Zoran, Frances, Louie, Marcia Sr., Maya, and Marmalade, who supported and challenged me through this journey – thank you!

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INTRODUCTION

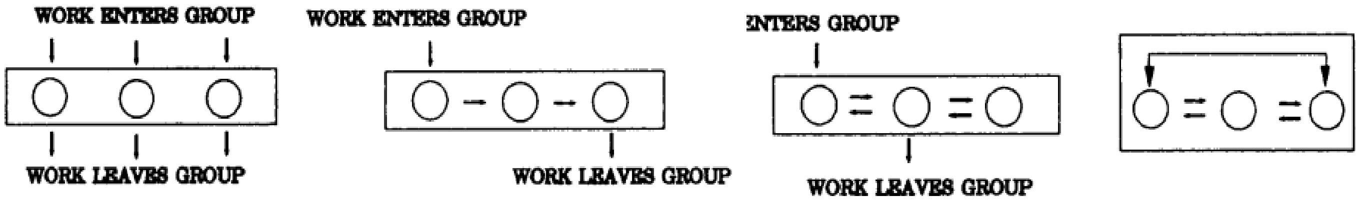
Organizations use teams to encourage employees to work together, often on tasks that require multiple people with different skills (Engestrom, 2008; Schrage, 1995). The benefits of teams are realized across contexts such as healthcare (Hughes et al., 2016), aviation (Cuevas, Fiore, Caldwell, & Strater, 2007), and software development (Faraj & Sproull, 2000). Teams generate ideas (Paulus, 2000), build products (Sethi, Smith, & Park, 2001), and respond to emergencies (Reddy et al., 2009). Fundamental to the definition of teams, which may lead to their success, is the concept of interdependence. Interdependence is the interaction between team members and the features of the team that determine how much team members rely on each other (Wageman, 1999).

Interdependence as a Construct

By definition, team members are interdependent. Sundstrom, de Meuse, and Futrell (1990, p. 120) define teams as “interdependent collections of individuals who share responsibility for specific outcomes”. Interdependence is present in many researchers’ definitions of teams (e.g., Atwal & Caldwell, 2006; Guzzo & Dickson, 1996; Jones & Harrison, 1996). Despite its centrality to the definition of teams, however, interdependence as a construct has been plagued with conceptual and measurement confusion. After Thompson (1967) established team interdependence, researchers measured this construct through the structure of group tasks as they appeared to observers. For example, one measure involved researchers matching the group’s work to pictures that represented one-way, sequential work, individual effort, or reciprocal interactions between members (Figure 1). Research that followed this measurement approach (i.e., structural interdependence) focused near-exclusively on task-related interdependence, which led to studies comparing types of sports (Timmerman, 2000) and task manipulations (Hirst & Yetton, 1999) with high and low interdependence. This measure of interdependence is a global property of the team (Klein & Kozlowski, 2000), as it exists only at the team level.

Once researchers began conducting field studies of teams in natural settings, they typically measured interdependence through self-report questionnaires instead of manipulating or rating interdependence directly. Through this process, multiple measures and multiple meanings of perceived interdependence appeared in the literature. This proliferation of interdependence types, many of them overlapping, contributes to much conceptual confusion. There are multiple subtypes of interdependence in the literature: feedback (Saavedra, Earley, & Van Dyne, 1993), goal (Tjosvold, Tang, & West, 2004), and reward interdependence (Wageman & Baker, 1997), which refer to the structure of outcomes (i.e., goals) and what the team receives after completing those outcomes (i.e., rewards and feedback). In addition, there are two subtypes of task interdependence: initiated and received task interdependence (Kiggundu, 1981), which respectively relate to the flow of information to, or from, the team member in question. Each interdependence subtype, when measured at the individual level and aggregated to the team level, is conceptualized as a shared team property (Klein & Kozlowski, 2000). Though team researchers may use the term interdependence for each subtype above, they measure this construct and its subtypes in very different ways. Appendix A demonstrates the multitude of interdependence measures used in the literature, indicating the measure proliferation that has occurred since perceived interdependence measures were first used.

Figure 1. *An early measure of interdependence as a global team property*.



Note. Image from measures of interdependence developed by Thompson, 1967 and Van de Ven, Debelcq, & Koenig, 1976.

Models of Interdependence

This conceptual confusion has led to confusion in interpreting the role of interdependence. On one hand, structural interdependence is a global property of teams that has no within-team variation and presumably no between-team variation, when all teams are completing the same task. On the other hand, perceived interdependence is considered a shared team property; thus, if measures rely on self-reports from team members, within-group agreement is expected. Under identical task conditions, however, individuals' responses can differ between- or within-teams to questions about team interdependence.

These forms of measurement correspond to different models of how interdependence relates to team processes. One model states that, because interdependence is part of the definition of teams, a team that is not interdependent is not a team (Lyubovnikova, West, Dawson, & Carter, 2015). This is interdependence model #1. Alternatively, interdependence is also treated as a variable that shapes (i.e., moderates) relations among other team-related constructs. In interdependence model #2, the correct "place" for interdependence is as a moderator. For example, the relation between team efficacy and performance is stronger when team interdependence is high than when team interdependence is low (but presumably not zero; Gully, Incalcaterra, Joshi, & Beaubien, 2002).

Given that across-team variation in interdependence is envisioned by (some) researchers, this raises the possibility of examining the effects of interdependence. Recently, researchers created a framework to examine aspects of this confusing situation. Specifically, Courtright, Thurgood, Stewart, and Pierotti (2015) introduced a new framework for the effects of team interdependence on team processes and outcomes. This approach is novel given that much previous work on team interdependence has followed the approaches specified in models #1 and #2 above. Previous research proposed that interdependence varied across tasks, but not within teams. This new conceptual framework predicts that interdependence is part of the causal chain of team process emergence. Under this new framework, teams with the same tasks may exhibit different interdependence levels, as these researchers consider interdependence a malleable behaviour, not a static property of the task. Courtright and colleagues (2015) propose a theory of how two broad categories of interdependence, namely task and outcome (Wageman, 1995), affect team performance through the independent pathways of task-relevant and social processes, respectively. This is model #3.

The Third Interdependence Model

Courtright and colleagues (2015) propose that *task interdependence* affects performance through task-related processes, such as task conflict, and self-efficacy. Conversely, they propose that *outcome interdependence* (i.e., goal, feedback, and reward interdependence) affects performance through relational processes, such as cohesion, process conflict, and relationship conflict. Their meta-analysis supported these relationships through correlations, and showed that the cross-relationships (i.e., between outcome interdependence and task-related processes and between task interdependence and relational processes) were significant but weaker than the hypothesized relationships. The significant cross-relationships temper support for this theory of two separate pathways, which suggests that further testing of the theory might clarify whether these cross-relationships are significantly different than the hypothesized relationships. Importantly, however, Courtright and colleagues (2015) have not directly tested this model in a single sample. A single sample approach, contrary to a meta-analytic approach, would allow a direct comparison of their theory, where all measures are collected in the same teams.

The mediating team processes tested in the meta-analysis of this new interdependence framework were composites of task-related and relational measures. To advance our understanding of interdependence, research must explore how team collaboration on tasks and outcomes are linked to unique team processes. Cohesion, a team process variable that is consistently related to team performance (e.g., Castano, Watts, & Tekleab, 2013), may connect interdependence to performance. Establishing these paths by collecting data from teams over multiple survey administrations would further support this new theory of team interdependence (Courtright et al., 2015).

Team Cohesion

Team cohesion has two subtypes, social cohesion and task cohesion (Brawley, Carron, & Widmeyer, 1987), in which task cohesion relates slightly more strongly to team performance than does social cohesion (Castano et al., 2013). Cohesion is defined generally as the group's tendency to work together (Carron, Brawley, & Widmeyer, 1998). As each team has a purpose, there is a task component of the group's cohesion (Hackman, 1976; MacCoun, 1996). Carron and Brawley (2012) call this the instrumental basis of cohesion. In addition, groups bond socially based on the need for belonging (Baumeister & Leary, 1995). Researchers have proposed that higher levels of interdependence in teams would lead to stronger cohesion (e.g., Barrick, Bradley, Kristof-Brown, & Colbert, 2007). In addition, interdependence interacts with the cohesion-performance relationship, such that teams with high interdependence had stronger cohesion-performance correlations than teams with low interdependence (Gully, Devine, & Whitney, 2012). The robust relationship between cohesion and performance suggests this variable may support interdependence model #3.

Interdependence's Impact on Performance

Previous research has explored older theories of how interdependence influences performance. The structural fit theory (Barnes, Hollenbeck, Jundt, De Rue, & Harmon, 2011) posits that both task interdependence and outcome interdependence must be high for the team to perform well. If one or both types of interdependence are low, then teams will not perform as well. This theory is called the structural fit theory because it advances the notion that interdependence is wholly determined by the *structure of the task*, and that *structure must fit the team context* to facilitate effective teamwork. Some research supports this theory (e.g., Saavedra, Earley, & Van Dyne, 1993; van der Vegt, Emans, & van de Vliert, 2000); however, this new model predicts (Courtright et al., 2015) that outcome and task interdependence may operate independently of each other and through separate team constructs. This theory advances that Behavioural measures of interdependence can vary in a manner not consistent with the view of interdependence as simply a moderator of other team processes' effects on team effectiveness. Preliminary meta-analytic research supports this theory (Courtright et al., 2015), yet directly testing these processes in a sample would provide a more stringent test of the unique contribution of each indirect path.

Hypotheses

Hypothesis 1: The effects of task interdependence on team performance will be mediated by task-related processes (i.e., task cohesion).

Hypothesis 2: The effects of outcome interdependence on team performance will be mediated by relational processes (i.e., social cohesion).

Hypothesis 3: The effects of task interdependence on team performance will be mediated by relational processes.

Hypothesis 4: The effects on outcome interdependence on performance will be mediated by task processes.

STUDY 1

METHOD

Participants

I collected questionnaire and project grade data from the members of 147 student project teams enrolled in an 8-month engineering design course at a large Canadian university in the 2016-2017 academic year. This engineering design course consisted of two two-month design projects completed sequentially in the first four months of the course, and one larger design project completed in the last four months of the course. Students grow their skills over the preliminary design projects and use these skills in their final, larger project. Each of the 582 students belongs to y one three- to five-member team (M = 3.96). The TeamWork Lab randomly assigned students to these teams with one restriction: students were randomly assigned within each classroom of approximately 50 students. I collected data from two surveys: one taken two and a half months into the teams' tenure (i.e., Survey 1), and the other, seven months into their team tenure (i.e., Survey 2). Of the 582 students, 390 were male, 105 were female, and 85 did not respond or were missing from this data collection point. The average age of the students was 18.4, with a standard deviation of 1.8.

Measures

I measured the following constructs in Survey 1: task interdependence (Langfred, 2005) and outcome interdependence (Van der Vegt, Van der Vliert, & Oosterhof, 2003). In Survey 2, I collected measures of social cohesion (developed by the Teamwork Lab) and task cohesion (developed by the Teamwork Lab). After the students completed the course, I obtained their final team-level project grades from their teaching assistants and professors.

Social Cohesion

Individual team members responded to an 8-item scale of social cohesion on a Likert-type scale from 1 to 7, with 1 = Completely Disagree to 7 = Completely Agree. This scale measures team members' attitudes about the team in a social context. An example question from this scale reads, "Our team has a positive social atmosphere." This measure was developed by the Teamwork Lab.

Task Cohesion

Task cohesion is measured with 8 items, each using a 7-point Likert-type scale from 1 = Completely Disagree to 7 = Completely Agree. Task cohesion, as distinct from social cohesion, measures the team's shared perception they are working on their tasks. An example reverse-coded item from this scale is, "Our team lacks unity when facing our goals and/or tasks." This measure was developed by the Teamwork Lab.

Outcome Interdependence

Outcome interdependence measures the degree to which teams share a common goal, receive feedback as a group, and receive rewards as a group. This measure (Van der Vegt et al., 2003) has six items and respondents select one of five Likert-type responses, from 1 = "Strongly Disagree" to 5 = "Strongly Agree". An example item reads, "We are collectively held accountable for our team performance."

Task Interdependence

Task interdependence measures the degree to which teams must collaborate on their work. I measured task interdependence with one five-item scale (Langfred, 2005). Each item is measured using a 7-point Likert-type scale from Strongly Disagree to Strongly Agree. An example item: "I need information and advice from my colleagues to perform my work well."

Performance

Students' performance in their teams is evaluated by their teaching assistants and professors in this course. Course instructors and assistants will assign grades out of 100 for three separate engineering design projects, which partially contribute to the final individual grades that students will receive. For this project, the third and final design project is the most appropriate outcome measure as teams completed the project through the second survey administration when I collected team process variables. This way, the team's task and social cohesion scores reflect their time working on this design project.

Analytic Procedure

To test the four hypotheses above, I first evaluated the predictor and mediator measures for reliability and factor structure. I calculated the interitem correlations of each measure using Cronbach's alpha (Cronbach, 1951) at the individual level. Next, I conducted individual and team confirmatory factor analyses (CFA) in MPlus (Muthen & Muthen, 2010) for both studies. For the individual data, I used the categorical function and for the team-level data I used continuous indicators. At the individual level, all four constructs in the CFA were measured with 5- and 7-point Likert-type scales. With 5-7 response options for each questionnaire, categorical and continuous measurement models can produce similar results (Bovaird & Koziol, 2012; Rhemtulla, Brousseau-Laird, & Savalei, 2012). However, the categorical model more accurately reflects the measurement properties of the questionnaires. I allowed all four latent factors to correlate with each other, and explored the CFA output for adequate model fit, problematic cross-loadings, and correlations between latent constructs.

Next, I tested the four main hypotheses in various ways. To closely reflect the propositions in the original Courtright and colleagues (2015) paper, I conducted a team-level path analysis in MPlus with indirect effects tested through standard significance tests. To better reflect the data I collected, I also conducted a two-level path analysis with indirect effects tested through the same format. Although bootstrapping the indirect effects is the preferred method of reducing bias (e.g., Shrout & Bolger, 2002), I did not use this bootstrapping approach in the team-level analysis as it was not available for the two-level analysis and using two forms of significance testing would complicate the interpretation of the results and the comparison of the two models.

As the two mediating variables (i.e., social and task cohesion) were highly correlated, any direct or indirect effects may be masked when both variables are present in the same model. To explore this, I conducted two multi-level path analyses with standard significance tests for indirect effects, one with task cohesion as the only mediator, therefore testing only Hypotheses 1 and 3, and one with social cohesion as the only mediator, therefore testing only Hypotheses 2 and 4. If these path analyses support the hypotheses whereas the earlier analyses do not, the high correlation between the two mediators may be hiding the true effects between predictors, mediators, and the outcome. Across all two-level analyses, I group-mean centered the individual-level variables and used the team averages at the team level. This strategy investigates the effects for each team member within his or her group at the individual level, and the absolute effect at the team level. However, a grand-mean centered strategy is more appropriate when one is not interested in individual-level, within-group effects, as group-mean centering the individual variables can better dissociate the individual- and team-level effects (Hoffman & Gavin, 1998; Kreft, de Leeuw, & Aiken, 1995). For all significance tests, I used two-tailed *p* values and reported standard errors. When missing data was present, I used pairwise deletion as the missing data was primarily due to attendance and attrition. For this reason, imputation seemed less appropriate in this situation than it would be if there were fewer missing data points (e.g., missing items in measures or missing measures in questionnaires).

RESULTS

Measure Reliability

The interitem reliabilities of the four self-report measures were all acceptable except for one relatively low Cronbach alpha value (Cronbach, 1951). Task interdependence, for example, had a Cronbach alpha of .71 which is not recommended for basic research (Nunnally, 1978) as it is below .80. The Cronbach's alpha for outcome interdependence is .85, for task cohesion it is .87, and for social cohesion it is .91, which are all acceptable.

Confirmatory Factor Analyses

Individual-Level Confirmatory Factor Analysis

To assess the measurement of each construct, I tested a CFA of all constructs in the model except the final performance grade. In this CFA model, I specified that all measures were categorical and I predicted that a four-factor solution with task interdependence, outcome interdependence, task cohesion, and social cohesion would fit the data well. I did not predict any indicators would cross-load onto other constructs for which they were not developed. The CFA had adequate, but not excellent fit, with an RMSEA of .092 and confidence intervals of .088 and .095. The CFI and TLI were above .9 but not above .95, at .932 and .926 respectively. When fit indices are below .9, they can be substantially improved (Bentler & Bonett, 1980). Based on these fit indices, the fit of this model could not be substantially improved, however, this model falls short of the stricter .95 cut-off recommended by Hu and Bentler (1999). The chi-square for the model fit is significant at 2157.2, $p < .001$, with 371 degrees of freedom. Consistent with the previous interdependence literature (e.g., Courtright et al., 2015), I allowed all constructs to correlate (Table 1). All standardized factor loadings were acceptable, ranging from .42 to .93 across indicators (Table 2). The suggested modifications were small and mainly recommended cross-loading interdependence indicators on other constructs, which is not consistent with theoretical predictions. Some of the smaller modification indices suggested three social cohesion items should load onto the task cohesion factor and that one item from the task cohesion measure should load onto the social cohesion factor.

Table 1. *Intercorrelations between latent variables from the individual-level Study 1 CFA.*

	1. Task Interdependence	2. Outcome Interdependence	3. Task Cohesion	4. Social Cohesion
2.	.17***			
3.	.09*	.35***		
4.	.09*	.26***	.84***	

Note. * = p < .05, *** = p < .001.

Table 2. *Standardized factor loadings from the individual-level Study 1 CFA.*

Indicator	Task Interdependence	Outcome Interdependence	Task Cohesion	Social Cohesion
TI1	.55			
TI2	.60			
TI3	.55			
TI4	.45			
TI5	.63			
TI6	.75			
TI7	.42			
OI1		.76		
OI2		.57		
OI3		.76		
OI4		.85		
OI5		.84		
OI6		.74		
TCOH1			.75	
TCOH2			.57	
TCOH3			.86	
TCOH4			.66	
TCOH5			.88	
TCOH6			.43	
TCOH7			.89	
TCOH8			.84	
SCOH1				.73
SCOH2				.90
SCOH3				.93
SCOH4				.80
SCOH5				.64
SCOH6				.73
SCOH7				.87
SCOH8				.85

Note. All factor loadings are significant at $p < .001$.

Team-Level Confirmatory Factor Analysis

To explore whether the team-level measurement of these constructs was isomorphic with the individual-level results, I conducted a CFA at the team level. In this CFA model, I specified that all measures were continuous and I predicted that a four-factor solution with task interdependence, outcome interdependence, task cohesion, and social cohesion would fit the data well. I did not predict that any cross-loadings would be significant. The CFA had poor fit, with an RMSEA of .101 and confidence intervals of .093 and .109. The CFI and TLI were low, at .82 and .81, respectively. This suggests the fit can be substantially improved (Bentler & Bonett, 1980). The chi-square for the model fit is significant at 1005.24, $p < .001$, with 400 degrees of freedom. The standardized root mean square residual was high at 0.101. I allowed all constructs to correlate (Table 3), and all latent variables were significantly correlated. All standardized factor loadings were above .40 except for the seventh item in the task interdependence scale, which loaded onto its factor at .30 (Table 4). The suggested modifications were small and mainly recommended cross-loading interdependence indicators on other constructs, which is not consistent with theoretical predictions. Despite the high correlation between task and social cohesion, the modification indices suggested that one task cohesion item should load onto the social cohesion factor, and one social cohesion item should load onto the task cohesion factor. This suggests the two subtypes are distinct, although highly correlated.

Table 3. *Intercorrelations between latent variables from the team-level Study 1 CFA.*

	1. Task Interdependence	2. Outcome Interdependence	3. Task Cohesion	4. Social Cohesion
2.	.22*			
3.	.24**	.23***		
4.	.22**	.21**	.88***	

Note. * = p < .05, ** = p < .01, *** = p < .001.

Table 4. *Standardized factor loadings from the team-level Study 1 CFA.*

Indicator	Task Interdependence	Outcome Interdependence	Task Cohesion	Social Cohesion
TI1	.66			
TI2	.65			
TI3	.60			
TI4	.48			
TI5	.59			
TI6	.73			
TI7	.30**			
OI1		.70		
OI2		.42		
OI3		.73		
OI4		.83		
OI5		.88		
OI6		.68		
TCOH1			.81	
TCOH2			.46	
TCOH3			.87	
TCOH4			.76	
TCOH5			.91	
TCOH6			.49	
TCOH7			.91	
TCOH8			.85	
SCOH1				.79
SCOH2				.93
SCOH3				.94
SCOH4				.85
SCOH5				.62
SCOH6				.76
SCOH7				.91
SCOH8				.91

Note. All factor loadings are significant at $p < .001$, except where ** = $p < .01$.

Team Aggregation

When measuring shared team perceptions using individuals' responses, researchers must justify aggregating individual team members' responses into an average that represents the team. Typically, researchers provide relevant "aggregation information" by examining intraclass correlations (ICCs) and r_{wg} statistics (e.g., Coultas, Driskell, Burke, & Salas, 2014; Klein & Kozlowski, 2000). The ICC1 measure reflects the percentage of variance at the team level as compared to the individual level (Bliese, 2000). Task interdependence had an ICC1 of .07, substantially below the .10 - .12 range that team researchers use (e.g., Kirkman, Rosen, Tesluk, & Gibson, 2004). Outcome interdependence had an ICC1 of .14, whereas task cohesion had a much higher ICC1 at .29, as did social cohesion at .41. These ICC1 values indicate that outcome interdependence, task cohesion, and social cohesion have substantial variance accounted for by team membership. However, task interdependence has less variance from team membership than from individual-level factors, suggesting relatively more within-team variability than between-team variability.

Path Analyses

Team-Level Path Analysis

To evaluate Courtright and colleagues' (2015) model at the level of analysis that they intended, I tested the path model at the team level by aggregating each team's scores on all variables. Given the relatively poor interitem reliability and aggregation statistics for the task interdependence measure, one limitation of aggregating these variables to the team level is that team scores on task interdependence may not reflect the true scores of the team members. I ran one path model with the hypothesized direct effects (i.e., task interdependence to task cohesion, outcome interdependence to social cohesion) and the crossed effects that Courtright and colleagues (2015) found significant in their meta-analysis (i.e., task interdependence to social cohesion, outcome interdependence to task cohesion). All predictor and mediator variables were regressed on the team's project grade, and all indirect paths (i.e., Hypotheses 1-4) were tested at once. This approach ensures that only the unique path through these variables is supported. Whereas this approach lowers the likelihood of finding a significant path when variables across separate paths are highly correlated, as are the cohesion constructs (see Table 5), testing all paths at once provides a stricter test of the hypothesized relationships.

This model was just-identified, as the number of parameters to be specified equaled the number of free parameters provided by the model. Although this means the model is not more parsimonious than the original data, it also means the relationships between the variables have been reproduced perfectly. Because of this, the chi-square test of model fit is zero, the RMSEA is zero, the CFI and TLI are 1.00, and the SRMR is zero. In a path analysis, the total fit of the model is of less importance than the tests of specific pathways. For this reason, I will focus on the indirect paths for each substantive (i.e., non-measurement) model. In the team-level path analysis, only the path from outcome interdependence to task cohesion to performance was supported, b = 1.50, SE = 0.73, p = .04 (Figure 2). This supports Hypothesis 4, that outcome interdependence's impact on project grades will operate through task cohesion. Both components of this path, task cohesion and outcome interdependence, predict teams' project grades; task cohesion positively at b = 3.62, SE = 1.39, p = .01, and outcome interdependence negatively at b = -3.09, SE = 1.16, p = .01. However, Hypotheses 1-3 were not supported, as no other pathways from task or outcome interdependence to grades held in this data set. Outcome interdependence predicts both task cohesion, b = 0.41, SE = .12, p = .001, and social cohesion, b = 0.36, SE = .14, p = .01. Task interdependence did not predict task cohesion, social cohesion, or project grades. All effects hold when the two mediating variables (i.e., task and social cohesion) are tested without the other type of cohesion.

Multilevel Path Analysis with Two Mediators

Poor aggregation statistics and low interitem reliability scores for the interdependence constructs suggest that team aggregation might not reflect the true relationships between these variables and the mediators collected at the individual level. To address this, I conducted a multilevel mediation analysis (i.e., a 1-1-2 mediation) using the procedure and code provided by Preacher, Zyphur, and Zhang (2010). To dissociate group-level effects from individual-level effects, I analyzed the relationships between interdependence and cohesion variables that were group mean centered at the within-team level and averaged at the between-team level. At the within-team (i.e., individual) level, outcome interdependence positively predicted social cohesion, b = 0.13, SE = 0.05, $p = .009$, and task cohesion, b = 0.20, SE = 0.04, $p < .001$. At the between-team (i.e., team) level, outcome interdependence had the same positive relationships with social cohesion, b = 4.33, SE = 1.22, $p < .001$, and task cohesion, b = 4.14, SE = 1.22, $p = .001$. Task interdependence was not related to any other construct, and no variables had significant, unique relationships with project grades.

However, as social and task cohesion are highly intercorrelated and are related to project grades in the team level analysis, the composite of these variables could predict project grades, even when there is no unique predictive ability of one variable (Johnson, 2000). For example, task cohesion does not significantly predict grades in this analysis, b = 6.96, SE = 3.60, $p = .05$, as it does not fall below the conventional significance level. Although this relationship was supported in the team-only analysis, multilevel analyses partition variance into individual and team levels which can restrict variance at the team level (Nezlek, 2008). Therefore, some relationships that exist in a team-only analysis may not be supported in a multilevel model. Of the hypothesized pathways, only the path from outcome interdependence to grades through task cohesion was significant, b = 28.85, SE = 9.70, $p = .003$. This supports Hypothesis 4, whereas Hypotheses 1-3 were not supported. This is consistent with the team-level analyses above, showing convergent results for these two analytic methods.

Multilevel Path Analysis with One Mediator

Social Cohesion. As social and task cohesion are highly correlated, I also analyzed the model separately for social and task cohesion as mediators. With only social cohesion as a potential mediator, the effect of outcome interdependence on social cohesion was supported at the individual level, b = 0.13, SE = 0.05, $p = .01$, and at the team level, b = 0.94, SE = 0.4, $p = .02$. As in the team-only (i.e., aggregated) path model, outcome interdependence negatively predicted project grades, b = -6.92, SE = 3.26, $p = .03$. However, task interdependence did not predict social cohesion at the individual or team level and did not predict project grades. Aggregate social cohesion did not predict project grades at the team level either. Neither indirect path through social cohesion was supported, in line with the model above.

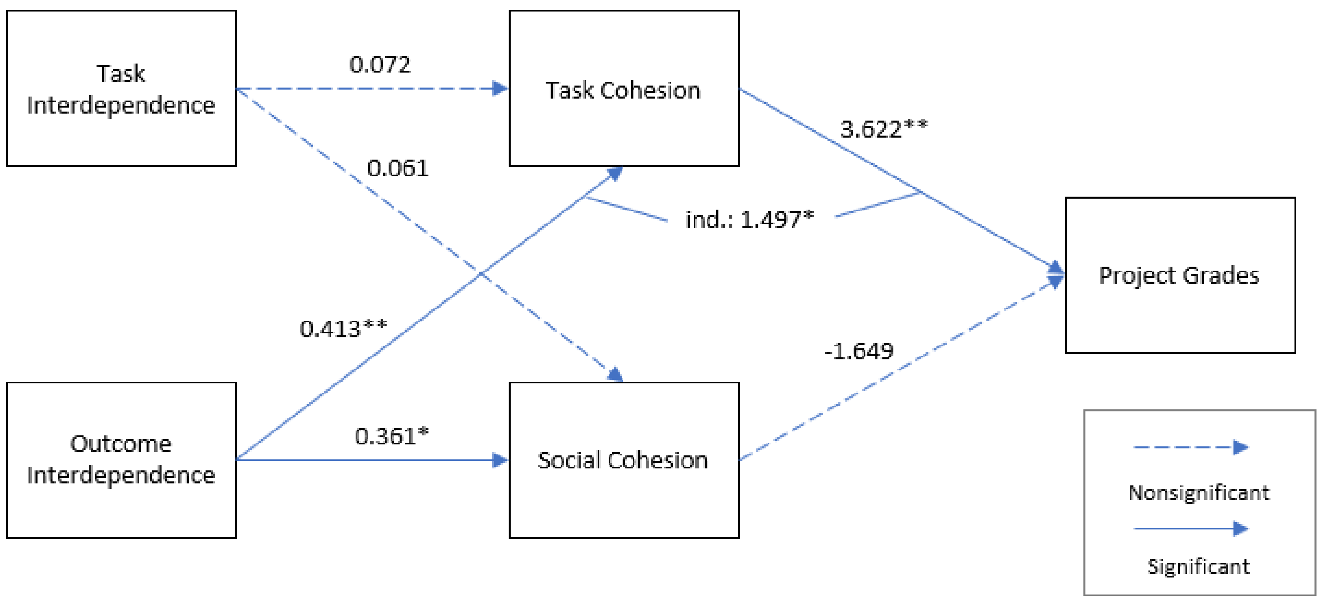
Task Cohesion. With task cohesion as the only potential mediator, outcome interdependence predicted task cohesion at the individual level, b = 0.22, SE = 0.05, $p < .001$, and at the team level, b = 0.98, SE = 0.36, $p = .006$. Outcome interdependence negatively predicted project grades, b = -8.09, SE = 3.27, $p = .01$, whereas aggregated task cohesion had a nonsignificant effect on project grades, b = 2.63, SE = 1.37, $p = .055$, and task interdependence did not predict team effectiveness. In the previous analysis, task interdependence significantly predicted project grades, but that did not hold in this analysis. Task interdependence did not predict task cohesion at the individual or team level. With this analysis, the pathway from outcome interdependence to project grades through task cohesion was not supported, whereas this indirect path was supported in the team-level model. It is possible that controlling for the individual-level effect of outcome interdependence on task cohesion reduced the strength of this indirect path. Finally, the path from task interdependence to project grades through task cohesion was not supported, meaning that all four hypotheses were not supported in this analysis.

Table 5. *Team-level intercorrelations between variables in the path analysis for Study 1.*

	Mean	Standard Deviation	1. Task Interdependence	2. Outcome Interdependence	3. Task Cohesion	4. Social Cohesion	5. Project Grades
1.	5.0	0.5					
2.	3.6	0.5	.23**				
3.	5.1	0.7	.12	.30***			
4.	5.1	0.8	.09	.23**	.82***		
5.	82.1	6.8	.07	-.14	.17*	.09	

Note. * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Figure 2. *Unstandardized team-level regression coefficients for the path analysis from interdependence to project grades through cohesion.*



Note. * = $p < .05$, ** = $p < .01$.

DISCUSSION

Of all hypotheses proposed in the path model, only Hypothesis 4 was supported at the team level and in the multilevel model with both cohesion mediators included. However, this path was not supported when task cohesion was analyzed separate from social cohesion. Hypothesis 4, which predicted that outcome interdependence predicts project grades through task cohesion, was not one of the two main predictions from previous research (Courtright et al., 2015). This – and the path from task interdependence to grades through social cohesion – are the cross-paths that had weaker relationships in the prior meta-analysis. Finding that paths through the opposite mediator are significant but without involvement of the intended mediator suggests that this model does not hold. As this sample consists of engineering student project teams, this may indicate that the proposed relationships do not generalize to this “engineering student team” context. However, it could also indicate a failure to replicate the relationships between constructs more generally or indicate challenges associated with the interdependence measures (e.g., unreliability or low validity).

Based on the distinction between task and social cohesion specified above, one would conclude that Courtright and colleagues’ (2015) major model propositions are not supported. However, the extremely high correlation between task and social cohesion complicates this interpretation, as a correlation above 0.7 for two constructs suggests they could be measuring the same concept (Carlson & Herdman, 2012). This new model of interdependence classified cohesion as a relational construct, without referring to the task-social cohesion distinction. For this reason, one could argue that cohesion should belong to the relational category of team constructs, meaning that all tests of cohesion as a mediator are testing Hypotheses 2 and 3. These guidelines, coupled with the high correlation between both cohesion types, suggest that a more central proposition of the Courtright et al. (2015) model was supported by these data than I expected. With this interpretation of cohesion’s role, Hypothesis 2 was supported and Hypothesis 4 was not tested. To test all four hypotheses based on the construct classifications that Courtright et al. (2015) put forth, future researchers should choose other variables better aligned to the researchers’ categories for mediators.

Task interdependence had low interitem reliability as measured by Cronbach's alpha, which may explain why there were no supported paths involving this construct. However, using the task interdependence construct in any form may introduce challenges that go beyond the specific measure in this sample. This research involves numerous self-report measures. It is possible, therefore, that the issues of self-reported team interdependence mentioned above contribute to this pattern of results, to low reliability, and to low team agreement. At the individual level, outcome interdependence had small, but significant, positive relationships with task and social cohesion; given that most research, understandably, is conducted at the team level, this provides further nuance to the literature on interdependence. In the second study, I attempt to replicate this analysis using another sample of student project team data to test the robustness of this pathway through outcome interdependence and task cohesion.

STUDY 2

METHOD

Participants

I collected questionnaire and project grade data from the members of 137 student project teams enrolled in an 8-month engineering design course at a large Canadian university during the 2017-2018 academic year. Each of the 550 students belonged to a three- to five-member team (M = 4.01). I collected data from two surveys: two and a half months into their team tenure (i.e., Survey 1), and seven months into their team tenure (i.e., Survey 2). Of the 550 students, 408 were male, 113 were female, 28 did not respond or were missing from this survey, and 1 indicated they prefer an alternate descriptor. Students' average age was 18.3, with a standard deviation of 1.6.

Measures

I collected the same outcome interdependence measure (Van der Vegt et al., 2003) at Surveys 1 and 2, but I collected a different measure of task interdependence (Van der Vegt & Janssen, 2003) from Study 1. Task interdependence was measured with five Likert-type items on a 7-point scale from 1 = "Strongly Disagree" to 7 = "Strongly Agree". An example is "I regularly have to communicate with colleagues about work-related issues." In Survey 2, I collected the same measures of social and task cohesion as in Study 1 (developed by the Teamwork Lab). After the students complete the course, I received their final project grades as in Study 1. Although the topic of the design project differs from year to year, the structure of the class reflects the projects from the previous study.

RESULTS

Measure Reliability

The interitem correlations for each multi-item measure are presented in Table 6. Alpha correlations for outcome interdependence, task cohesion, and social cohesion were all above the recommended cut-off of 0.7 for early-stage research and 0.8 for basic research (Nunnally, 1978). However, the interitem correlations for task interdependence did not meet either cut-off at both surveys. Further analyses indicated that no one item from this five-item scale was uniquely problematic; that is, in no case across the two surveys would removing an item improve the Cronbach's alpha statistic.

Table 6. *Interitem correlations (i.e., Cronbach's alpha coefficients) for measures in Study 2.*

Measure	**Alpha**	**Number of Items**
Task Interdependence – Survey 1	.61	5
Outcome Interdependence – Survey 1	.81	6
Task Interdependence – Survey 2	.66	5
Outcome Interdependence – Survey 2	.86	6
Task Cohesion	.85	8
Social Cohesion	.89	8

Confirmatory Factor Analyses

Individual-Level Confirmatory Factor Analysis

As in Study 1, I conducted a CFA of all categorical constructs in this model, including task and outcome interdependence at both data collection times without the final performance measure. In this CFA model, I specified a six-factor solution with two task and outcome interdependence factors, task cohesion, and social cohesion. I expected this measurement model would fit the data well if these latent variables were correlated. I also correlated the residuals when respondents answered the same questionnaire items at two data collection times. For example, the residuals for item one of task interdependence at Survey 1 were correlated with the residuals for item one of task interdependence at Survey 2. The CFA had adequate, but not excellent, fit with an RMSEA of .077 and confidence intervals of .074 and .08. The CFI and TLI were near .9, at .907 and .898 respectively. The chi-square for the model fit is significant at 2643.4, $p < .001$, with 639 degrees of freedom. Across two surveys, one indicator's standardized factor loading was very low, at .15 from Survey 1 and .23 from Survey 2. This may have led to the poor fit of the model. All other factor loadings were between .39 and .92. The major suggested modifications from the model were cross-loading interdependence indicators on cohesion factors, which is not consistent with theoretical predictions. The modification indices suggested that three task cohesion items should load onto social cohesion, but that no social cohesion items should load onto the task cohesion factor. The intercorrelations between latent variables are shown in Table 7 and the standardized factor loadings are shown in Table 8.

Table 7. *Intercorrelations between the individual-level Study 2 CFA latent factors.*

	1. Task Interdep. Survey 1	2. Outcome Interdep. Survey 1	3. Task Interdep. Survey 2	4. Outcome Interdep. Survey 2	5. Task Cohesion	6. Social Cohesion
2.	.19***					
3.	.55***	.09				
4.	.05	.50***	.08			
5.	.05	.24***	-.04	.39***		
6.	.05	.12*	-.01	.27***	.81***	

Note. * = $p < .05$, *** = $p < .001$.

Table 8. *Factor loadings from the Study 2 individual-level CFA.*

Indicator	Task Interdependence Survey 1	Outcome Interdependence Survey 1	Task Interdependence Survey 2	Outcome Interdependence Survey 2	Task Cohesion	Social Cohesion
TI1 – S1	.70					
TI2 – S1	.15**					
TI3 – S1	.79					
TI4 – S1	.39					
TI5 – S1	.50					
OI1 – S1		.77				
OI2 – S1		.45				
OI3 – S1		.78				
OI4 – S1		.80				
OI5 – S1		.79				
OI6 – S1		.69				
TI1 – S2			.66			
TI2 – S2			.23			
TI3 – S2			.71			
TI4 – S2			.57			
TI5 – S2			.67			
OI1 – S2				.74		
OI2 – S2				.67		
OI3 – S2				.73		
OI4 – S2				.86		
OI5 – S2				.81		
OI6 – S2				.81		
TCOH1					.73	
TCOH2					.53	
TCOH3					.85	
TCOH4					.66	
TCOH5					.86	
TCOH6					.43	
TCOH7					.84	
TCOH8					.81	
SCOH1						.71
SCOH2						.88
SCOH3						.92
SCOH4						.77
SCOH5						.66
SCOH6						.72
SCOH7						.87
SCOH8						.80

Note. All factor loadings significant at $p < .001$ except **, which was significant at $p = .004$.

Team-Level Confirmatory Factor Analysis

I then conducted a CFA at the team level with continuous indicators and a six-factor solution with two factors of task interdependence, one from Survey 1 and another from Survey 2, two factors of outcome interdependence, each from the survey administrations, task cohesion, and social cohesion. I predicted all the factors would correlate and there would be no significant cross-loadings. The CFA had poor fit, with an RMSEA of .099 and confidence intervals of .093 and .106. The CFI and TLI were very low at .74 and .72, respectively. This suggests the fit can be greatly improved (Bentler & Bonett, 1980). The chi-square for the model fit is significant at 1498.57, $p < .001$, with 650 degrees of freedom. The standardized root mean square residual was high at 0.119. I allowed all constructs to correlate (Table 9), and most standardized factor loadings were above .40, whereas six items had low loadings (Table 10). Despite the high correlation between task and social cohesion, the modification indices suggested that four task cohesion items should load onto the social cohesion factor, and no social cohesion items should load onto the task cohesion factor. This suggests that the two cohesion subtypes are generally distinct with the social cohesion factor relating to more items than the task cohesion factor. However, the constructs could be measured more precisely to avoid this potential confusion and overlap.

Table 9. *Intercorrelations between the team-level Study 2 CFA latent factors.*

	1. Task Interdep. Survey 1	2. Outcome Interdep. Survey 1	3. Task Interdep. Survey 2	4. Outcome Interdep. Survey 2	5. Task Cohesion	6. Social Cohesion
2.	.13					
3.	.28*	-.04				
4.	-.02	.41***	.15			
5.	.13	.01	.24*	.20*		
6.	-.02	.03	.22*	.18	.84***	

Note. * = p < .05, *** = p < .001.

Table 10. *Factor loadings from the Study 2 team-level CFA.*

Indicator	Task Interdependence Survey 1	Outcome Interdependence Survey 1	Task Interdependence Survey 2	Outcome Interdependence Survey 2	Task Cohesion	Social Cohesion
TI1 – S1	.65					
TI2 – S1	.37					
TI3 – S1	.73					
TI4 – S1	.39					
TI5 – S1	.34**					
OI1 – S1		.61				
OI2 – S1		.30				
OI3 – S1		.64				
OI4 – S1		.82				
OI5 – S1		.84				
OI6 – S1		.71				
TI1 – S2			.72			
TI2 – S2			.21*			
TI3 – S2			.86			
TI4 – S2			.58			
TI5 – S2			.47			
OI1 – S2				.63		
OI2 – S2				.49		
OI3 – S2				.67		
OI4 – S2				.87		
OI5 – S2				.82		
OI6 – S2				.72		
TCOH1					.73	
TCOH2					.38	
TCOH3					.89	
TCOH4					.59	
TCOH5					.93	
TCOH6					.35	
TCOH7					.90	
TCOH8					.82	
SCOH1						.69
SCOH2						.91
SCOH3						.92
SCOH4						.77
SCOH5						.62
SCOH6						.67
SCOH7						.92
SCOH8						.87

Note. All factor loadings significant at $p < .001$, except * = $p < .05$ and ** = $p < .01$.

Team Aggregation

Team aggregation values, based on data from both surveys, indicate that task and social cohesion have substantial variance accounted for by team membership, but task and outcome interdependence have relatively little variance accounted for at the team level. The task interdependence measure has an ICC1 of .06 in Survey 1 and .05 in Survey 2, whereas outcome interdependence has an ICC1 of .08 in Survey 1 and .10 in Survey 2. Task cohesion and social cohesion have much higher ICC1 values, at .30 and .36, respectively. However, aggregation cut-offs should be used as one of multiple indicators that one should aggregate constructs to the team level. The team referent of these measures and the nested nature of the students suggest that I should analyze these data at the team level.

Path Analyses

Path Analyses with Survey 1 Interdependence

Team-Level Path Analysis. As Study 2 incorporates interdependence data from two surveys, I conducted two replications of the path model in Study 1. The first replication includes task and outcome interdependence at Survey 1, and task and social cohesion at Survey 2. In this replication of the analysis in Study 1, with interdependence measured at the second team data collection point, none of the four paths from interdependence to project grades through cohesion were supported (see Figure 3 for regression coefficients). As well, none of the path's components were supported, potentially due to the high correlation between task and social cohesion (see Table 11 for the correlation matrix). However, this correlation was also high in Study 1, and one of the four proposed paths were supported. The model was just-identified, so all fit statistics were perfect and did not provide any useful information for interpreting the model fit to the data. When analyzing task cohesion separately from social cohesion, task cohesion predicted project grades, b = 2.70, SE = 1.06, p = .01, but no indirect paths were supported. No relationships were significant when analyzing social cohesion independently, and task interdependence was not related to any other constructs across analyses. Another potential issue is the higher amount of missing data in this sample: team member attendance was much lower at Survey 1 than Survey 2, which led to fewer teams overall and more missing data within teams. This could lead to restricted ranges for the interdependence constructs, particularly if substantial "missingness" was non-random in nature (e.g., less engaged, weaker, or more disaffected students were missing; e.g., Roth, 1994; Sackett & Yang, 2000).

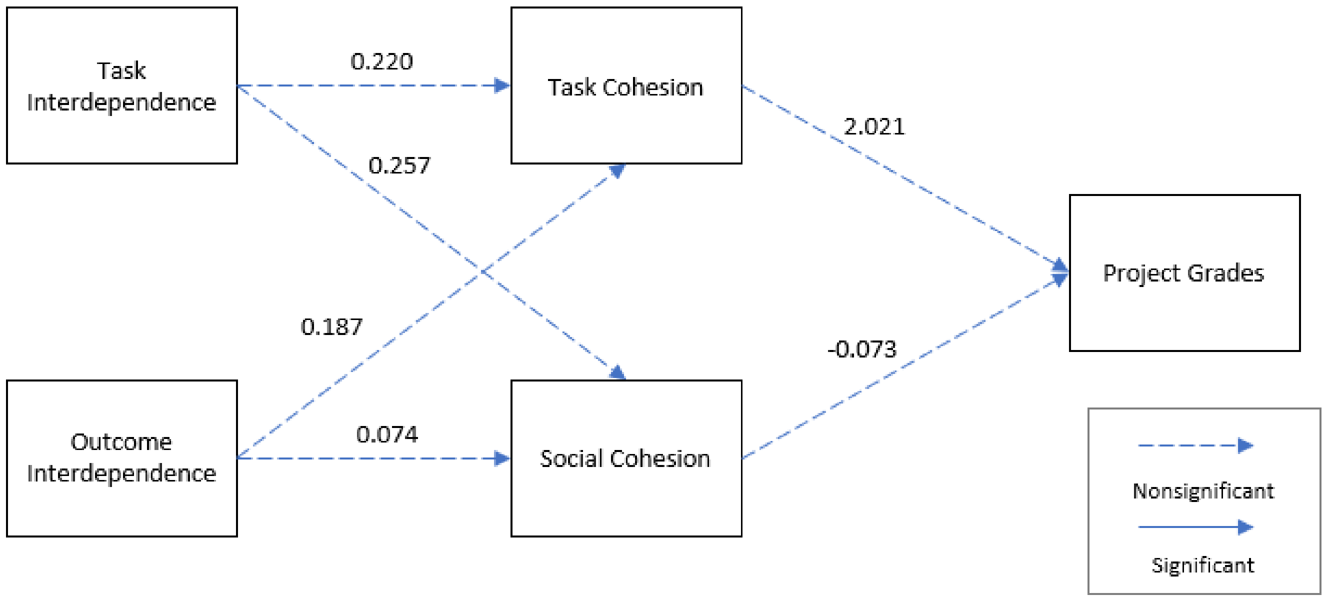
Individual-Level Path Analysis. When testing the model at the individual and team levels, outcome interdependence is related to task cohesion, b = 0.15, SE = 0.03, $p < .001$, and social cohesion, b = 0.09, SE = 0.04, $p = .01$, within the project teams. To ensure the individual-level effects were only present within the teams, I group mean centered both cohesion variables so that interdependence predicted scores relative to each group's average. At the team level, task interdependence and outcome interdependence were not related to either cohesion measure. Further, none of these predictor or mediator variables were related to the final project grades, and no pathways were supported. When analyzing social cohesion separately from task cohesion in the model, social cohesion predicts project grades at the team level, b = 1.61, SE = 0.78, $p = .04$, yet no other team-level effects, including indirect paths, were observed. At the individual level, I found the same link between outcome interdependence and social cohesion, b = 0.1, SE = 0.4, $p = .01$. In an analysis of the model with only task cohesion as a mediator, outcome interdependence was associated with task cohesion at the individual level, b = 0.16, SE = 0.4, $p < .001$. At the team level, project grades were not significantly predicted by any of the preceding variables. Task cohesion, which was a significant predictor of project grades in the team-level analysis, was unrelated to grades in this multilevel analysis, b = 1.98, SE = 1.11, $p = .07$. Although some construct pairs were related, none of the study's hypotheses were supported in this analysis.

Table 11. *Correlation matrix for the path analysis in Study 2 using interdependence at Survey 1.*

	Mean	Standard Deviation	1. Task Interdep. Survey 1	2. Outcome Interdep. Survey 1	3. Task Cohesion	4. Social Cohesion	5. Project Grades
1.	4.4	0.5					
2.	4.7	0.6	.16				
3.	5.1	0.7	.18*	.20*			
4.	5.3	0.8	.17*	.09	.79***		
5.	81.2	6.1	.08	.15	.24**	.18*	

Note. * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Figure 3. *Unstandardized team-level regression coefficients for the Study 2 model.*



Note. Task and outcome interdependence were measured in Survey 1.

Path Analyses with Survey 2 Interdependence

I tested the same path model with another set of interdependence measures in this data set – those collected from Survey 2 with the cohesion measures. This may inflate the relationships between these two variables, as they were collected in the same session and therefore could have common method variance (Spector, 2006). The notion of interdependence may be clearer to the team members after having worked together for approximately 4-5 more months after I administered Survey 1. The relationship between predictor and mediator variables may be stronger and team's interdependence scores may be more accurate as the teams had more time together to develop a shared understanding of interdependence, but this is weakened by the reduced causal inference of any supported pathways. One of the three requirements for causal inference is that the cause must precede the effect in time (Pearl, 2010). Collecting predictor and mediator variables in the same survey reduces the number of causal inference steps supported at this stage to one; that there is an association between the two variables.

Team-Level Path Analysis. Analyses of the team-level interdependence data collected in Survey 2 did not provide support for the four indirect path hypotheses. None of the interdependence or cohesion measures significantly predicted project grades, yet outcome interdependence predicted both task cohesion, b = 0.35, SE = .09, $p < .001$, and social cohesion, b = 0.27, SE = 0.11, $p = .01$ (Figure 4). When using only task cohesion, the indirect path from outcome interdependence to task cohesion to team project grades was unsupported, b = 0.56, SE = 0.32, $p = .08$. In this analysis, outcome interdependence was related to task cohesion, b = 0.34, SE = 0.09, $p > .001$ but not to project grades, b = 1.47, SE = 0.87, $p = .09$; similar to the analysis with interdependence measures from Survey 1. Task cohesion is not significantly related to project grades, b = 1.63, SE = 0.81, $p = .045$. When analyzing social cohesion separately, outcome interdependence is related to social cohesion, b = 0.27, SE = 0.11, $p = .01$, and to project grades, b = 1.73, SE = 0.85, $p = .04$. However, the original four hypotheses of indirect paths between interdependence and grades through cohesion were not supported when analyzing interdependence measures from Survey 2. The interdependence scores from Survey 2 reflected teams that worked together for many months longer than scores in Survey 1. The correlation matrix for these analyses are represented in Table 12.

Multilevel Path Analysis. In addition to testing this model at the team level, I conducted a multilevel path analysis with interdependence and cohesion measures at both levels and project grades at the team level. At the individual level, task interdependence was related to task cohesion, b = -0.11, SE = 0.03, $p < .001$, and social cohesion, b = -0.08, SE = 0.04, $p = .02$. This relationship was negative for both cohesion measures, which is the opposite of my expectations and of Courtright and colleagues' (2015) meta-analytic results from the team level. Outcome interdependence was related to task cohesion, b = 0.17, SE = 0.03, $p < .001$, and social cohesion, b = 0.11, SE = 0.03, $p = .001$, in the expected direction (i.e., positively) within teams. At the between-team level, outcome interdependence was positively related to task cohesion, b = 2.56, SE = 0.24, $p < .001$, and social cohesion, b = 2.49, SE = 0.31, $p < .001$. Task interdependence was significantly related to social cohesion, b = 3.08, SE = 1.43, $p = .03$, and unrelated to task cohesion, b = 2.23, SE = 1.23, $p = .07$. This negative relationship between task interdependence and both types of cohesion at the individual level is contrary to expectations, yet it may reveal that interdependence and cohesion operate differently within the team compared to between teams. However, as this relationship was not supported in two earlier tests of the model (i.e., in Study 1 and when interdependence was measured at Survey 1 in Study 2), it may be an artifact of common method variance from measures collected in the same survey. At the team level, none of the predictor or mediator variables were related to project grades, and none of the four indirect paths showed a relationship between interdependence, cohesion, and grades altogether. This means hypotheses 1-4 were not supported.

Path Analysis with Task Cohesion as the Sole Mediator. When including task cohesion as the only mediator in the model, the overall pattern of the results was similar, with some key differences in predicting project grades. Task interdependence was negatively related to task cohesion at the individual level, b = -0.11, SE = 0.03, $p = .001$, and outcome interdependence was positively related to task cohesion within the teams, b = 0.17, SE = 0.03, $p < .001$. Between teams, outcome interdependence was related to task cohesion, b = 1.21, SE = 0.34, $p < .001$, yet task interdependence was not related to task cohesion. Contrary to the multilevel model results, in which both cohesion variables were included as potential mediators, task interdependence negatively predicted project grades in this analysis, b = -13.07, SE = 6.12, $p = .03$, and outcome interdependence positively predicted grades, b = 11.00, SE = 4.55, $p = .02$. However, neither path through task cohesion was supported in this analysis, consistent with other results in Study 2, but inconsistent with results in Study 1. This means hypotheses 1 and 3 were not supported across Study 2.

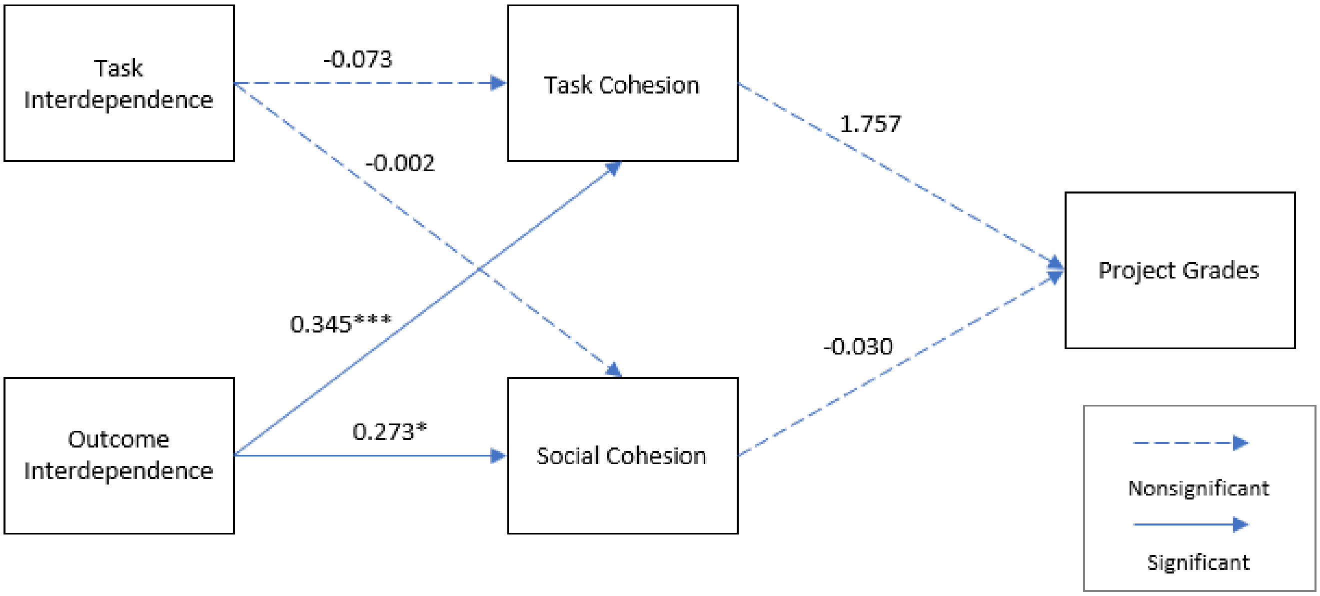
Path Analysis with Social Cohesion as the Sole Mediator. With social cohesion as the only potential mediator, the individual-level and team-level relationships are similar to the model with only task cohesion as a potential mediator. Task interdependence is negatively related to social cohesion within teams, b = -0.08, SE = 0.04, $p = .03$, and outcome interdependence is positively related to social cohesion within teams, b = 0.11, SE = 0.03, $p = .001$. Outcome interdependence is positively related to social cohesion between teams, b = 1.07, SE = 0.45, $p = .02$. However, task interdependence is not related to social cohesion between the project teams. Task and outcome interdependence both predict project grades, b = -13.77, SE = 5.93, $p = .02$, for task, and b = 11.41, SE = 3.76, $p = .002$, for outcome interdependence. Neither path through social cohesion was supported in this analysis, indicating that hypotheses 2 and 4 were not supported across Study 2.

Table 12. *Correlation matrix for the path analysis in Study 2 using interdependence at Survey 2.*

	Mean	Standard Deviation	1. Task Interdep. Survey 2	2. Outcome Interdep. Survey 2	3. Task Cohesion	4. Social Cohesion	5. Project Grades
1.	4.3	0.5					
2.	4.8	0.6	.21*				
3.	5.1	0.7	.01	.32***			
4.	5.3	0.8	.05	.23**	.79***		
5.	81.2	6.1	- .10	.20*	.24**	.18*	

Note. * = p < .05, ** = p < .01, *** = p < .001.

Figure 4. *Unstandardized team-level regression coefficients for the second path analysis in Study 2 (i.e., where task interdependence was captured in Survey 2).*



Note. * = $p < .05$, *** = $p < .001$.

DISCUSSION

In Study 2, interdependence measures were collected at two times in the team's life cycle. This offered two opportunities to replicate the effects in Study 1. Based on data collected in Survey 2, none of the four hypotheses predicting indirect effects from interdependence through cohesion were supported, meaning I did not replicate the effects in Study 1. In the team-level analysis, none of the components of these pathways were supported either. This means that the first analysis of Study 2 does not replicate the results reported in Study 1. Nor does it replicate the meta-analytic findings on which the present research is based (Courtright et al., 2015). There may be multiple reasons why these paths were not supported in Study 2. I used a measure of task interdependence that differed from that used in earlier research. This measure could be a poorer measure of task interdependence, meaning this measure might lead to a poorer test of the theoretical model. However, using a different measure of task interdependence should not influence the results substantially, as task interdependence did not contribute to any significant pathways in Study 1. Another possible explanation involves missing data; Survey 1, when I first administered the interdependence measures, had much more missing data (i.e., incomplete responses within participants or missing participants) than did Survey 2, when I administered both interdependence and cohesion measures. Specifically, Survey 1 was missing 28% of participants, Survey 2 was missing 13% of participants, and only 2% of project grades were missing. These project grades were unavailable because of student attrition; the 12 students who left the course before completing it did not receive grades. As these students responded to other measures in our data set, we included them in the non-grade analyses. This missing data reduces the individual-level data and restricts the number of sufficiently complete teams. This could also change the distribution of interdependence scores, assuming the missing respondents differ systematically on interdependence. Finally, the specifics of the task may have changed from Study 1 to Study 2, meaning that interdependence may have played a smaller role in teams' shared perceptions and in their performance.

I also conducted analyses at both the individual and team levels with interdependence collected at Survey 2. In both analyses, outcome interdependence was positively related to task and social cohesion with smaller effect sizes at the individual level than at the team level. This pattern was not predicted by the new interdependence model; it is consistent, however, with the concept of perceptual interdependence. In contrast to structural interdependence, self-reported perceptions of interdependence may differ across individuals in teams *and* positively relate to individuals' perceptions of cohesion. One portion of the pathway detailed in Hypothesis 4 (i.e., from outcome interdependence to task cohesion to grades) was supported in the multilevel analysis, but only with task cohesion as a mediator. Outcome interdependence was positively related to task cohesion, which is consistent with the results from Study 1.

When testing the model with interdependence at Survey 2, none of the four hypotheses were supported. This means that no indirect paths from interdependence to project grades were positive and significant. Some *components* of the indirect paths, however, were supported. Specifically, outcome interdependence was related to task and social cohesion. When task cohesion was removed from the analysis, leaving only social cohesion as a mediator, outcome interdependence was slightly related to project grades between teams. The effects at the individual level were small and negative, which is not consistent with the positive individual-level effects reported above. Results of the multilevel model analysis indicates that task interdependence is related negatively to project grades whereas outcome interdependence is positively related to grades.

As can be seen, the results are mixed depending on which analysis or which source of interdependence is included (i.e., Survey 1 or Survey 2). Overall, however, Study 2 does not support the four indirect pathways from interdependence to grades through cohesion. While these variables may be correlated, as in the earlier meta-analysis (Courtright et al., 2015), the analytic methods used in these studies to investigate unique predictors and indirect pathways may not mirror the simple correlations.

GENERAL DISCUSSION

In these student project teams, interdependence appears not to lead reliably to team cohesion and cohesion does not appear to lead to project success across analyses. In both studies, the measurement models fit the data well, yet the path analyses do not support the proposed model of interdependence. Only one indirect path in one study was significant, and prior researchers expected this path from outcome interdependence through task cohesion to be weaker than the opposite path from task interdependence through task cohesion. However, the high correlation between task and social cohesion suggests that these participants may think of cohesion as a single construct, with very high overlap between the items that are meant to measure task-focused cohesion and those meant to measure social cohesion. Interpreting the results with this information suggests that one of the new interdependence model's main hypotheses may be supported although it does not seem to be the case at first glance. Specifically, one could consider the pathway from outcome interdependence to task cohesion to project grades as supporting the relational pathway from outcome interdependence to grades through social team constructs (i.e., Hypothesis 2).

Although some components of these pathways were significant, these findings were inconsistent across studies and analyses (i.e., team-level and multilevel analyses) which do not fully replicate the new interdependence model. Further, the individual-level, within-team analyses show inconsistent results, where two of the three analyses had significant positive relationships between outcome interdependence and cohesion, yet the third analysis with interdependence and cohesion from Survey 2 found a significant negative relationship. All effect sizes for these individual results were small yet significant due to the large sample size at the within-group level. The changing direction of the effects within teams and the lack of replication across between-team effects suggests these findings are not especially robust to different samples and/or team types. Most surprising, perhaps, is that task interdependence was not related to cohesion or performance across the data sets; given the importance of task interdependence in the literature and its effects as a moderator in meta-analyses, one would expect this form of interdependence to impact team processes. Whereas multiple forms of measurement plagued the task interdependence literature, there is no evidence so far that certain measures produce effects for interdependence whereas others do not. Until we discover otherwise, previous research suggests that task interdependence should relate to team processes and outcomes (e.g., Gully et al., 2012).

Limitations

There are numerous limitations associated with this set of studies, including 1) failing to directly replicate the analysis, 2) using different measures, 3) finding less-than-ideal fit for the measurement model, 4) having poor psychometric properties for the task interdependence measures, 5) missing data potentially impacting the results, 6) limits on generalizability, and 7) a high correlation between task and social cohesion. The first limitation of this study is both a detriment and a benefit; the meta-analysis first testing this new theory of interdependence compiled the intercorrelations between each part of the model to show that each two-way relationship was significant (Courtright et al., 2015). In this test of the model, I employed a more complex and stringent path model approach with regression coefficients and indirect pathways instead of descriptive correlations. Had I analyzed these data in the same manner as the original authors, I would have found more support for the model. Specifically, Study 1 confirmed significant correlations between all but two pairs of constructs: only the correlation between task and outcome interdependence and the correlation between outcome interdependence and social cohesion were not significant. In Study 2, all correlations but two were significant, yet these two relationships were different from those in Study 1: task interdependence was not significantly correlated with task cohesion or social cohesion. Whereas the magnitudes of these significant correlations differed, more components of the model are supported when using this correlational approach than when using the path model approach.

Another limitation is that I used different measures of interdependence across the two studies. On one hand, the inconsistency between studies is problematic, as the two studies were not direct replications of each other. On the other hand, using different measures demonstrates the degree of convergent validity between the two measures of task interdependence. The difference in the correlations between task interdependence and other key constructs in these studies suggested that the differences between the Langfred (2005) measure and the Van der Vegt and Janssen (2003) measure may play a role. These measures also contributed to less-than-ideal model fit when analyzing the measurement model; specifically, the task interdependence measure in Study 2 (Van der Vegt & Janssen, 2003) had one particularly poor item loading which contributed to the poor fit of the model. With poor model fit and poor interitem reliability, one could argue that task interdependence scores should not be averaged across all items in this measure. As the validity of a measure is limited by its reliability (Clearly, Linn, & Walster, 1970), the nonsignificant relationships between task interdependence and other constructs may come from its poor measurement properties.

Two additional limitations of these studies are that missing data can have an impact on individual- and team-level effects and that problems with generalizability from this sample may exist. Missing data that is not completely random can influence the relationships between measures at the individual level (Switzer & Roth, 2002). Further, the impact of missing data can compound at the team level (Maloney, Johnson, & Zellmer-Bruhn, 2010). Future research could address this limitation by sampling populations where missing data is not present, by conducting simulation studies to identify the impact of missingness, or by using multiple imputation methods to replace the missing data. Finally, the samples for both studies are student project teams, which differ from most organizational teams in two major ways. Students in the first year of their university programs typically have minimal work experience and may not have worked in teams in the past, whereas organizational teams are more likely to have members with work and team experience. This limits my ability to generalize effects from this population to older workers in groups within organizations. Further, project teams differ from many organizational work teams due to the defined length of time they are working together (Chiocchio, Kelloway, & Hobbs, 2015). Whereas teams in organizations may work together indefinitely, the mandated end date of a project team's lifespan may change the level of interdependence, the attitude of team members towards each other, or the level of cohesion the team feels. If these differences are related to key constructs in this interdependence model, this data source may not be an accurate reflection of organizational teams or of the broader team literature.

Future Research

Despite these limitations, this new model of interdependence may help us reconceptualize where interdependence belongs in the causal chain of team processes. However, this model may not be supported in project teams, or it may be limited by poor measurement of interdependence from the literature. Clearly, more work is needed to clarify the construct of interdependence, to agree on a reliable and valid measure of its subtypes, and to re-test this model with a broader set of mediating variables. Perhaps researchers could compare and contrast this model with previous models of interdependence, including the structural fit hypothesis (i.e., Model #2; Barnes et al., 2011) and the conceptualization of interdependence as an exclusion criterion (i.e., Model #1; Lyubovnikova et al., 2015). By comparing team outcomes across all these models, researchers will advance our collective understanding of interdependence's role, along with differential effects that may arise from subtypes such as task and outcome interdependence. The broad categories of task and relational team processes from Courtright and colleagues (2015) also require further research to understand specific team mediators such as team conflict, collective efficacy, and potency. Team effectiveness, the outcome measure used in this set of studies, is not, of course, the only important team outcome. Future research should examine both objective and subjective performance ratings and other important outcome variables (e.g., team satisfaction, team member retention).

Conclusion

Interdependence is crucial to our understanding of teams. By better understanding how team members rely on each other, we can help organizational teams of all types operate more efficiently and with fewer process losses. This research also helps to further our understanding of team emergent states, including their antecedents and outcomes. As researchers call for more time-based analyses of team processes (e.g., Marks, Mathieu, & Zaccaro, 2001), longitudinal studies such as these that incorporate work group emergent states can clarify when and how one group characteristic or perception leads to a shared feeling among group members. This research can lead to better team task designs, team composition models, and more accurate reward structures to motivate teams more effectively.

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APPENDIX A

Self-Report (i.e., Perceptual) Measures of Interdependence

Table 13. *Inventory of interdependence measures, their origins, and subsequent uses of the measure.*

Measure	Foundations of the Measure	Citations and Adaptations
Allen, Sargent, & Bradley, 2003		
Ang, van Dyne, & Begley, 2003		
Ayupp & Kong, 2010	Kiggundu, 1983; P&G, 1991; van der Vegt et al., 1998	
Bishop, 1995	P&G, 1991; Campion, Medsker, & Higgs, 1993	
Bruner, Eys, Evans, & Wilson	van der Vegt et al., 1998; van der Vegt et al., 2000	
Bruner, Hall, & Cote, 2011	Van der Vegt et al., 1998; Van der Vegt et al., 2000	
Campion, Medsker, & Higgs, 1993		De Dreu & West, 2001; Aube & Rousseau, 2005; Cullinane, Bosak, Flood, & Demerouti, 2014; Stark, Shaw, & Duffy, 2007; Basaglia, Caporarello, Magni, & Pennarola, 2010; Ghitulescu, 2013; Shen, Gallivan, & Tang, 2008; Jiang, Gu, & Wang, 2015; Guenter & Grote, 2012
Cleavenger, Gardner, & Mhatre, 2007		
Costa, 2000		ten Brummelhuis, Johns, Lyons, & ter Hoeven, 2016
Evans & Eys, 2015	Bruner et al., 2011; Van der Vegt et al., 2001	
Fairchild & Hunter, 2014	Kiggundu, 1983	
Fragale, 2006		
Fry, Kerr, & Lee, 1986		
Hertel, Konradt, & Orlikowski, 2004	P&G, 1991 as modified by Liden, Wayne, & Bradway, 1997	
Huang, Barbour, Su, & Contractor, 2013		
Janssen, Van de Vliert, Veenstra, 1999		De Dreu & West, 2001; De Dreu, 2007
Jarvenpaa & Staples, 2000		Rode, 2016
Kiggundu, 1983		Moye & Langfred, 2004; Neubert & Taggar, 2004; Stewart, Courtright, & Barrick, 2012; Settoon & Mossholder, 2002; Wong, 2008; Stewart & Barrick, 2000
Kirkman & Shapiro, 2000		Lin, 2015
Koster, Stokman, Hodson, & Sanders, 2007		
Langfred, 2005	Kiggundu, 1983	Barnett & McCormick, 2016; Buljac, Van Woerkom, & Van Wijngaarden, 2013
Langfred, 2000	Shanley & Langfred, 1997	
Linden, Erdogan, Wayne, & Sparrowe, 2006	Pearce & Gregersen, 1991	
Loughry & Tosi, 2008	Mohr, 1971; P&G, 1991; Campion et al., 1993	
Lyubovnikova, West, Dawson, & Carter, 2015		
Maynard, Mathieu, Rapp, & Gilson, 2012	Tesluk, Mathieu, Zaccaro, & Marks, 1997; Van de Ven, Debelcq, & Koenig, 1976	

Molleman, 2009		
Morgeson & Humphrey, 2006		Dierdoff, Rubin, & Bachrach, 2012
Pearce & Gregersen (P&G), 1991		Hu & Liden, 2011; 2015; Golden & Veiga, 2005; Emich, 2014; Liden, Wayne, & Bradway, 1997; Chattopadhyay, 1999; Ozer, Chang, & Schaubroeck, 2014; Peng, 2012; Bartel, Saavedra, & van Dyne, 2001; Cooper, 2013 Goldberg, Riordan, & Schaffer, 2010; Shin, Kim, Choi, & Lee, 2016; Spanu, Baban, Bria, Lucacel, Florian, & Rus, 2013; Chattopadhyay & George, 2001; George, Chattopadhyay, & Zhang, 2012; Wu & Lee, 2016; Ferguson & Barry, 2011; Vidyarthi, Singh, Erdogan, Chaudhry, Posthuma, & Anand, 2016; Lee, 2015 Bartel, 2001; Liden, Wayne, Jaworski, & Bennett, 2004; Shin & Eom, 2014; Chattopadhyay, George, & Shulman, 2008; Bartel & Saavedra, 2000; Eby, Meade, Parisi, & Douthitt, 1999; Li, Mitchell, & Boyle, 2016; Jen, 2013; Rispens, 2012 Shin & Choi, 2010; ten Brummelhuis, Johns, Lyons, & ter Hoeven, 2016; Parker & Allen, 2001; Alavi & McCormick, 2008; Aube, Rousseau, Mama, & Morin, 2009; Allen, Sargent, & Bradley, 2003; Aube, Rousseau, & Tremblay, 2015 Vidyarthi, Anand, & Liden, 2014; Aube & Rousseau, 2016; Hoon & Tan, 2008; Zhang, Hempel, Han, & Tjosvold, 2007; Bacharach, Bamberger, & Vashdi, 2005; Anderson & Williams, 1996; Hershcovis, Reich, Parker, & Bozeman, 2012
Pearce, Sommer, Morris, & Frideger, 1992		Pearce, 1993
Ramamoorthy & Flood, 2004		
Rapp, Gilson, Mathieu, & Ruddy, 2016		
Runhaar et al., 2010		Beverborg, Sleegers, & van Veen, 2015
Saavedra, Earley, & van Dyne, 1993		
Salvaggio, Streich, Hopper, & Pierce, 2011	Hackman & Oldham, 1975	
Sambasivan, Siew-Phaik, Mohamed, & Leong, 2011		
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Schaeffner, Huettermann, Gebert, Boerner, Kearney, & Song, 2015		
Shaw, Duffy, & Stark, 2000	Campion et al, 1993	
Sprigg, Jackson, & Parker, 2000	Campion et al, 1993	
Staples & Webster, 2008	Bishop & Scott, 2000; Janssen et al., 1999	Teng & Luo, 2015
Tjosvold, Andrews, & Jones, 1983		Zhang, Hempel, Han, & Tjosvold, 2007
Tjosvold, Law, & Sun, 2003		Leung, Deng, Wang, & Zhou, 2015

van de Ven, Delbecq, & Koenig, 1976	Thompson, 1967	Troster, Mehra, & van Knippenberg, 2014; Mia & Goyal, 1991
Van der vegt & Janssen, 2003	Van der Vegt et al., 2001	Bachrach, Powell, Bendoly, & Richey, 2006; Rico, Alcover, Sanchez-Manzanares & Gil, 2009; Rico, Bachrach, Sanchez-Manzanares, & Collins, 2011; Bachrach, Powell, Collins, & Richey, 2006; Bendoly, Bachrach, & Wang, 2006
Van der Vegt et al., 2001	Tjosvold, 1984; Van der Vegt, Emans, & Van de Vliert, 1999	Van der Vegt & Van de Vliert, 2005; Rico & Cohen, 2005; de Jong, Curseu, & Leenders, 2014; Liu, Hernandez, & Wang, 2014; Chen, Tang, & Wang, 2009; Peltokorpi & Hasu, 2014; Acuna, Gomez, & Juristo, 2009; Ortega, Sanchez-Manzanares, Gil, & Rico, 2010; 2013; Erkutlu & Chafra, 2015
van der Vegt et al., 2003	Van der Vegt et al., 2001	Knapp & Ferrante, 2014; Somech, Desivilya, & Lidogoster, 2009
Van der Vegt, Emans, & Van de Vliert, 1998	Kiggundu, 1983; Pearce & Gregersen, 1991	Taggar & Haines, 2006; Haines & Taggar, 2006
Van der Vegt, Emans, & Van de Vliert, 2000	Kiggundu, 1983; P&G, 1991; Mohr, 1971; Van der Vegt et al., 1998	Sadler-Smith, El-Kot, & Leat, 2003; Schippers, den Hartog, Koopman, & Wienk, 2003; Leung, Wang, Zhou, & Chan, 2011; Biron & Boon, 2013; Regts & Molleman, 2013; Frenkel & Sanders, 2007
Wageman & Gordon, 2005		
Wageman, 1995		Nielsen, Bachrach, Sundstrom, & Halfhill, 2012; Hon & Chan, 2013
Wageman, Hackman, & Lehman, 2005		McClelland, Leach, Clegg, & McGowan, 2014
Wang, Yen, & Liu, 2015		
Wong & Campion, 1991		
Wong, DeSanctis, & Staudenmayer, 2007		
Yuan, Fulk, Monge & Contractor, 2010		

APPENDIX B

Team Aggregation – R_{wg} Values

Team Aggregation for Study 1 – R_{wg} Values

Regarding r_{wg} estimates, the average values are all acceptable. However, the range of r_{wg} values shows that some teams have poor agreement. To provide context, the number of teams who do not meet conventional cut-offs of 0.6 and 0.7 (e.g., Bliese, Halverson, & Schreisheim, 2002; James, 1988) are included in Table 14. However, using r_{wg} cut-offs such as .7 or .6 are problematic; some researchers state they are too lenient (e.g., Harvey & Hollander 2004), whereas others suggest alternative tests of aggregation (e.g., Coultas et al., 2014).

Table 14. *R_{wg} values for Study 1.*

Variable	Average R_{wg}	Range of R_{wg} values	# of teams below .7 / .6
Task Interdependence	.78	.31 - .95	24 / 8
Outcome Interdependence	.75	.08 - .97	43 / 24
Task Cohesion	.81	.28 – 1.00	22 / 8
Social Cohesion	.84	.48 - .99	11 / 5

Team Aggregation for Study 2 - R_{wg} Values

R_{wg} values are calculated for all teams of three or more respondents on each measure. The average r_{wg} values are all acceptable; however, the range of r_{wg} values shows that some teams have poor agreement. The number of teams below conventional cut-offs of 0.6 and 0.7 (Bliese et al., 2002; James, 1988) are included in Table 15. Although some teams do not pass these cut-off criteria, there are various challenges with aggregation cut-offs; therefore, they should be used as one of multiple indicators that one should aggregate constructs to the team level.

Table 15. *R_{wg} values for Study 2.*

Variable	Average R_{wg}	Range of R_{wg} values	# of teams below .7 / .6
Task Interdependence – Survey 1	.78	.40 - .98	11 / 6
Outcome Interdependence – Survey 1	.76	.37 - .98	20 / 9
Task Interdependence – Survey 2	.77	.36 - .96	27 / 12
Outcome Interdependence – Survey 2	.76	.17 - .98	33 / 17
Task Cohesion	.81	.43 – .97	19 / 8
Social Cohesion	.83	.54 - .99	12 / 2

APPENDIX C

Ethics Approval Forms

Figure 5. *Ethics approval form for Study 1.*

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Amendment Approval Notice

Principal Investigator: Prof. Natalie Allen
Department & Institution: Social Science\Psychology,Western University

NMREB File Number: 108317
Study Title: Understanding Engineering Project Teams (2016-2017)
Sponsor: Social Sciences and Humanities Research Council

NMREB Revision Approval Date: October 24, 2016
NMREB Expiry Date: September 12, 2017

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Instruments	Questionnaire 3	2016/10/14
Revised Western University Protocol	Received Oct 14, 16	

The Western University Non-Medical Science Research Ethics Board (NMREB) has reviewed and approved the amendment to the above named study, as of the NMREB Amendment Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Figure 6. *Ethics approval form for Study 2.*

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Delegated Initial Approval Notice

Principal Investigator: Prof. Natalie Allen
Department & Institution: Social Science\Psychology, Western University

NMREB File Number: 109667
Study Title: Understanding Engineering Project Teams (2017-2018)

NMREB Initial Approval Date: September 08, 2017
NMREB Expiry Date: September 08, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Received September 4, 2017	
Recruitment Items	Recruitment Script	2017/09/03
Letter of Information & Consent		2017/09/03
Instruments	Questionnaire 1 - Received August 8, 2017	
Instruments	Questionnaire 2 - Received August 8, 2017	2017/08/08
Instruments	Questionnaire 3 - Received August 8, 2017	
Instruments	Questionnaire 4 - Received August 8, 2017	
Instruments	Alternative Assignment - Received August 8, 2017	

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the above named study, as of the NMREB Initial Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

APPENDIX D

Questionnaire Items

Questionnaire Items for Study 1

Please provide your **first name** for data coding purposes:

____

Please provide the **last 4 digits** of your student ID number for data coding purposes:

____

Please provide your **Studio (Section)** number: _______

Were you enrolled in a different **studio/section** for the September survey?

YES ____ NO____

If YES, what **studio/section** were you in previously? ______

Please provide your ES1050 Design Studio Project **Team** number: _________

Were you on a different **team** during the September survey?

YES____ NO____

If YES, what **team** were you on previously? _____

Please circle the number that best represents your agreement with each statement. When responding to each statement, please consider **your team as a whole**. Please assume that all references to **"work"** refer to the work of your design team in this course.

Task Interdependence Langfred, 2005	Strongly Disagree								Strongly Agree
1. The team works best when we coordinate our work closely.	1	2	3	4	5	6	7	8	9
2. Team members have to work together to get group tasks done.	1	2	3	4	5	6	7	8	9
3. The way individual members perform their work has a significant impact on others in the team.	1	2	3	4	5	6	7	8	9
4. My work cannot be done unless other people do their work.	1	2	3	4	5	6	7	8	9
5. Most of my work activities are affected by the activities of other people on the team.	1	2	3	4	5	6	7	8	9
6. Team members frequently have to coordinate their efforts with each other.	1	2	3	4	5	6	7	8	9
7. We cannot complete a project unless everyone contributes.	1	2	3	4	5	6	7	8	9

Please circle the number that best represents your agreement with each statement. When responding to each statement, please consider **your team as a whole**.

Task Cohesion	Completely Disagree	Disagree	Somewhat Disagree	Neither Agree Nor Disagree	Somewhat Agree	Agree	Completely Agree
1. Our team is focused on the work we have to do.	1	2	3	4	5	6	7
2. We do not agree on what needs to be done.	1	2	3	4	5	6	7
3. Team members work together to meet goals and objectives.	1	2	3	4	5	6	7
4. Our team lacks unity when facing our goals and/or tasks.	1	2	3	4	5	6	7
5. We are committed to helping the team perform well.	1	2	3	4	5	6	7
6. Team members put their personal goals ahead of team goals.	1	2	3	4	5	6	7
7. Our team is determined to work together to optimize performance.	1	2	3	4	5	6	7
8. Our team sticks together when our work gets tough.	1	2	3	4	5	6	7

Please circle the number that best represents your agreement with each statement. When responding to each statement, please consider **your team as a whole**.

Social Cohesion	Completely Disagree	Disagree	Somewhat Disagree	Neither Agree Nor Disagree	Somewhat Agree	Agree	Completely Agree
1. Members of our team do not get along with each other.	1	2	3	4	5	6	7
2. Relationships in our team are pleasant and relaxed.	1	2	3	4	5	6	7
3. We enjoy being part of our group.	1	2	3	4	5	6	7
4. We treat each other in a friendly manner.	1	2	3	4	5	6	7
5. Our team does not want to spend more time together than we have to.	1	2	3	4	5	6	7
6. We do not enjoy socializing or spending time with each other.	1	2	3	4	5	6	7
7. Our team has a positive social atmosphere.	1	2	3	4	5	6	7
8. Members of our team feel like they "fit in."	1	2	3	4	5	6	7

Please circle the number that best represents your agreement with each statement. When responding to each statement, please consider **your team as a whole**. Please assume that all references to **"work"** refer to the work of your design teams in this course.

Outcome Interdependence Van der Vegt et al., 2001	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
1. We receive feedback about our team performance.	1	2	3	4	5
2. We are collectively held accountable for our team performance.	1	2	3	4	5
3. We receive regular feedback about our team functioning.	1	2	3	4	5
4. We are informed about the goals we should attain as a group.	1	2	3	4	5
5. We regularly receive information about what is expected from our team.	1	2	3	4	5
6. We have several clear targets we have to attain as a group.	1	2	3	4	5

Questionnaire Items in Study 2

Please circle the number that best represents your agreement with each statement. When responding to each statement, please consider **your team as a whole**. Please assume that all references to **“work”** refer to the work of your design teams in this course.

Task Interdependence Van der Vegt & Janssen, 2003	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
1. I need information and advice from my colleagues to perform my work well.	1	2	3	4	5	6	7
2. I have a one-person task; it is not necessary for me to coordinate or cooperate with others.	1	2	3	4	5	6	7
3. I need to collaborate with my colleagues to perform my work well.	1	2	3	4	5	6	7
4. My colleagues need information and advice from me to perform their work well.	1	2	3	4	5	6	7
5. I regularly have to communicate with colleagues about task-related issues.	1	2	3	4	5	6	7

Note. Only task interdependence was measured differently in Study 2 than in Study 1.

CURRICULUM VITAE

Natasha Ouslis

Education

PhD in Industrial/Organizational Psychology, University of Western Ontario 2018–2022
Supervisor: Dr. Natalie Allen

MSc in Industrial/Organizational Psychology, University of Western Ontario 2016–2018
Thesis: Testing a Theory of Team Interdependence
Supervisor: Dr. Natalie Allen

Hon. BSc in Psychology, High Distinction, University of Toronto 2012–2016
Thesis: Search templates' influences in attentional tasks
Supervisors: Dr. Jay Pratt, Dr. Ian Spence

Research Experience

Collaboration with Dr. Saurin Patel Jan 2017–Present
Biases in mutual fund team performance
Ivey Business School, University of Western Ontario

Research Assistant, Supervisor: Dr. Sonia Kang April 2016–April 2017
Emotion regulation in the workplace
Rotman School of Management, University of Toronto

Thesis Student, Supervisor: Dr. Jay Pratt April 2015–April 2016
The interaction between visual working memory and attention
Visual Cognition Laboratory, University of Toronto

Research Volunteer, Supervisor: Dr. Jennifer Campos May 2014–May 2015
Action video game training effects on driving performance in older adults
Toronto Rehabilitation Institute

Researcher, Supervisor: Dr. Susanne Ferber Mar 2014–April 2015
Working memory precision and sensory processing
Cognitive Neuroscience Laboratory, University of Toronto

Lab Manager and Research Assistant, Supervisor: Dr. Ian Spence April 2013–Aug 2016
Gender differences in spatial ability, working memory, and attention
Engineering Psychology Laboratory, University of Toronto

Research Assistant, Supervisor: Dr. Adam Anderson Mar 2013–May 2014

The effect of disgust and fear induction on sexual orientation judgment
Affect and Cognition Laboratory, University of Toronto

Publications

Rajsic, J., **Ouslis, N.E.,** Wilson, D.E., & Pratt, J. (2017). Looking sharp: Becoming a search template boosts precision and stability in visual working memory. *Attention, Perception, & Psychophysics, 1-9.*

Lowe, M.X., Stevenson, R.A., Wilson, K.E., **Ouslis, N.E.**, Barense, M.D., Cant, J.S., & Ferber, S. (2016). Sensory processing patterns predict the bias of ensemble statistics for items held in visual working memory. *Journal of Experimental Psychology: Human Perception and Performance, 42*(2), 294-301.

Conference Presentations

Ouslis, N.E. & Allen, N.J. (2018, July). *Testing a new model of team interdependence.* Poster at the INGRoup Conference, Washington, DC.

Ouslis, N.E. & Allen, N.J. (2017, July). *Conceptual and measurement challenges: The case of task interdependence.* Poster Presentation at the Interdisciplinary Group Research Meeting, St. Louis, MO.

Allen, N.J., Stanley, D.J., Cameron, K., McMenamin, J., **Ouslis, N.E.,** Lee, H., & Woodley, H. (2017, July). *Group Performance: A 10-year Bibliometric Review of Conceptualizations and Assessment.* Talk at the Interdisciplinary Group Research Meeting, St. Louis, MO.

Ouslis, N.E. & Allen, N.J. (2017, June). *Team interdependence: Conceptual and measurement challenges.* Poster Presentation at the Canadian Psychological Association Meeting, Toronto, ON.

Rajsic, J., **Ouslis, N.E.,** Wilson, D.E., & Pratt, J. (2016, November). *Looking sharp: Becoming a search template boosts precision and stability in visual working memory.* Psychonomic Society Meeting, Boston, MA

Pereira, B.J., **Ouslis, N.E.,** & Spence, I. (2015, May). *Controlling exposure time in mental rotation reduces gender differences.* Poster Presentation at the Association for Psychological Science meeting, New York City, NY

Ouslis, N.E., Pereira, B.J., & Spence, I. (2015, March). *Gender Differences in Speed and Response Bias of Three-dimensional Mental Rotation*. Poster Presentation at the Women in Science and Engineering Conference, Toronto, ON

Lowe, M.X., Stevenson, R.A., Wilson, K.E., **Ouslis, N.E.**, Azimi, M., Barense, M.D., Cant, J.S., & Ferber, S. (2015, March). *Sensory Processing Patterns Predict the Bias of Ensemble Statistics for Items*

Held in Visual Working Memory. Poster Presentation at the Cognitive Neuroscience Society, San Francisco, CA

Ouslis, N.E., Pereira, B.J., & Spence, I. (2015, February). *Gender Differences in Speed and Response Bias of Three-dimensional Mental Rotation*. Poster Presentation at the Lake Ontario Visionary Establishment, Niagara Falls, ON

Ouslis, N. E., Pereira, B. J., Jeong, J. Y., & Spence, I. (2014, July*). Attention and Visuo-spatial Working Memory in Mental Rotation*. Poster Presentation at the Canadian Society for Brain, Behaviour, and Cognitive Sciences, Toronto, ON

Awards and Honours

Joseph A. Bombardier Canada Graduate Scholarship – Doctoral ($105,000) University of Western Ontario	Sept 2018–Aug 2021
Ontario Graduate Scholarship ($15,000) - declined University of Western Ontario	Sept 2018–Aug 2019
Joseph A. Bombardier Canada Graduate Scholarship – Masters ($17,500) University of Western Ontario	Sept 2017–Aug 2018
Ontario Graduate Scholarship ($15,000) – declined University of Western Ontario	Sept 2017–Aug 2018
Ontario Graduate Scholarship ($15,000) University of Western Ontario	Sept 2016–Aug 2017
Douglas N. Jackson Memorial Award ($500) University of Western Ontario	Sept 2016
Association for Psychological Science Student Travel Award ($440)	May 2015
Arts and Science Student Union Travel Award ($400) University of Toronto	February 2015
Gail Ferris Sheard Academic Scholarship ($787) University College, University of Toronto	September 2015
Co-awarded (B. Pereira), PI (I. Spence): Undergraduate Research Fund ($1500) *Exploring Gender Differences in Shepard-Metzler Mental Rotation Performance*	2014–2015
Joel Verwegen Undergraduate Research Award ($500) Toronto Rehabilitation Institute, University Centre	2014

Dean's List — 2012–2016
University of Toronto

Co-Curricular Experience

Colloquium Committee Member, Psychology Department, Western University — May 2017–April 2018

Graduate Student Judge, Western Student Research Conference — March 2017

Graduate Student Advisor, Western Undergraduate Psychology Journal — Sept 2016–Present

Editor-in-Chief, Inkblot: Psychology Undergraduate Journal — Sept 2015–Sept 2016
Editor, Inkblot: Psychology Undergraduate Journal — Oct 2014–Sept 2015
University of Toronto

Academic Coordinator, Psychology Students` Association — April 2014–April 2015
University of Toronto