The Impact of Control Belief and Learning Disorientation on Cognitive Load: The Mediating Effect of Academic Emotions in Two Types of Hypermedia Learning Environments

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ABSTRACT
The present study tested the influence of control belief, learning disorientation, and academic emotions on cognitive load in two types of concept-map structures within hypermedia learning environment. Four hundred and eighty-five students were randomly assigned to two groups: 245 students in the hierarchical group and 240 students in the networked group. Multi-group invariance and mediation analysis were applied to test the mediating effects of academic emotions in the association between control belief, learning disorientation and cognitive load (extraneous, intrinsic, and germane load) across groups. Results indicated all models were invariant across the groups. Control belief and learning disorientation were antecedents of positive and negative emotions; extraneous load in turn was affected by positive and negative emotions, whereas intrinsic and germane loads were only influenced by positive emotions. Learning disorientation had positive effect on extraneous load, whereas control belief had positive affect on intrinsic and germane load. The results are discussed in light of the integration of learning disorientation and non-cognitive factors with cognitive load.

Keywords: Control belief, learning disorientation, academic emotions, cognitive load, hypermedia learning environment

INTRODUCTION
Recent research highlights the importance of investigating the contributions of emotions and motivation to the complex phenomenon of cognitive load (Mayer & Estrella, 2014). The roles of emotions on cognitive load in multimedia environments have been examined by applying the emotional design, defined as the use of different design features to influence emotions. For example, the results of a study indicated that the emotional design induced positive emotions, reduced task difficulty and increased performance, but did not significantly affected cognitive load (Plass, Heidig, Heyward, Homer, & Um, 2014). Another study using emotional design showed that participants who experienced the induction of positive emotions and learned using the positive design had longer fixation—that is, more sustained attention to multimedia—than participants who experienced the induction of positive emotions but learned using the negative design, and participants who experienced the induction of negative emotions and learned using the positive or negative design; the emotional design was not significantly affect cognitive load, situational interest, and task difficulty (Park, Knorzer, Plass, Brünken, 2015).

These findings are in contrast with the results of research in an English language class context which showed that anxiety increased cognitive load (Chen & Chang, 2014). However, studies to date have not examined specific types of cognitive load. Thus the question, “How do academic emotions affect specific types of cognitive load?” is still underspecified. Addressing this question, the present study tests the mediational role of academic emotions on extraneous, intrinsic, and germane cognitive loads. Control belief and learning disorientation are considered as antecedents of academic emotions, because control belief is an appraisal property of academic emotions (Pekrun, 2006), and learning disorientation is a well-known problem in the hypermedia (Dias, Gomes, & Correia, 1999). This model was tested in two types of concept-map structures within hypermedia environment: hierarchical and networked.

Direct Effect of Control Belief and Learning Disorientation on Cognitive Load
Control belief, which can be defined as a belief that efforts will result in positive outcomes (Pintrich, Smith, Garcia, & McKeachie, 1991), has a direct influence on cognitive performance. A pilot study showed that self-

efficacy was associated with cognitive load in term of a better working memory performance (Vasile, Marhan, Singer, & Stoicescu, 2011). The other study showed that self-efficacy increased problem solving and efficiency, but had limited effect on time (Hoffman & Schraw, 2009). Since self-efficacy is related to control belief (You & Kang, 2014), those findings support the prediction of control belief to enhance working memory performance through the use of cognitive strategies. You and Kang (2014) showed that control belief positively predicted the use of self-regulated learning strategies.

Learning disorientation is defined as the tendency to lose one's sense of location and direction in a nonlinear document (Ahuja & Webster, 2001). The influence of learning disorientation on cognitive load was demonstrated in previous research showing that learning disorientation positively predicted cognitive load (Amadeu, Tricot, & Marine, 2009). Furthermore, the authors analyzed that learning disorientation was a source of extraneous load, but their analysis lacked empirical supported. Accordingly, the current study aimed at clarifying the direct effect of learning disorientation on specific types of cognitive load.

In the current study, cognitive load is defined as the number of element information which needs to be processed in working memory before commencing meaningful learning (Paas, vanGog, & Sweller, 2010). Most studies consider three types of cognitive load: extraneous load, which is caused by the presentation of irrelevant information during the learning task; intrinsic load, which concerns the complexity of interactivity among elements inherent in the information; and germane load, which refers to the efforts of processing and creating new information (Sweller, 2010). To optimize learning performance, the instruction should reduce extraneous load, manage intrinsic load and promote germane load (Sweller, Ayres, & Kalyuga, 2011). In the hypermedia learning environment, extraneous load comes from the complexity of hypermedia design, whereas intrinsic load relates to the complexity of hypermedia contents and learning tasks.

Academic Emotions as Mediators between Control Belief, Learning Disorientation and Cognitive Load

Academic emotions are thought to be mediating constructs that link control belief and learning disorientation with cognitive performance. This notion is supported by the social-cognitive control-value theory of academic emotions (Pekrun, 2006) and the cognitive-affective theory of learning with media (CATLM) (Moreno, 2006). The control-value theory of academic emotions postulates that control belief has an appraisal function of academic emotions (Pekrun, 2006). When students judge themselves to have high control over environmental factors, positive emotions will be experienced. The reverse is also true: when students have low control, they will experience negative emotions. The CATLM proposes the affective mediation assumption which suggests that motivational and emotional factors mediate learning by increasing or decreasing cognitive engagement (Moreno, 2006), including cognitive load. Reeve, Bonaccio and Winford (2014) made a conclusion based on their study that positive emotions facilitate cognitive performance through decreasing distraction, but negative emotion hinder cognitive performance through increasing distraction. Although learning disorientation is not accounted in the academic emotions theory, the study demonstrated that learning disorientation had a huge impact on emotions (Tan & Wei, 2006).

Previous studies have supported the mediating role of academic emotion between perceived control and learning disorientation with cognitive load. The studies have found that, in classical and online learning contexts, students who had high control belief led to increase in positive emotions and a decrease in negative emotions (Bieg, Goetz, Hubbard, 2013; Lichtenfeld, Pekrun, & Stupnisky, Reiss, & Murayama, 2012; You & Kang, 2014). Learning disorientation also has influence on academic emotions. Users felt interested when they experienced less of a feeling of being "lost" while visiting the web (Tan & Wei, 206), so that their learning effort increase (Shih, Huang, Hsu, & Chen, 2012).

Studies on the effects of emotions on cognitive performance show inconsistent results. Therefore, there are two opposing hypotheses regarding the impact of emotions on learning, namely the emotions-as-facilitator-of-learning hypothesis, which assumes that emotions enhance the learning process, and the emotions-as-suppressor-of-learning hypothesis which postulates that emotions interfere with the learning process (Park, et al, 2015). Supporting the first hypothesis, a study showed that hope positively predicted learning strategies in online and traditional learning (2009). The hindering effects of emotions on cognition and learning are discussed in cognitive load theory. In line with the second hypothesis, Chen and Chang (2009) showed that anxiety positively predicted cognitive load in English listening performance.

Concept-Map Structure as Navigation System of Hypermedia Environment

The concept-map structure is a graphical representation of the conceptual organization of an area of knowledge that is used to assist users to make a series of selections as they go through a complex document (Rouet & Potelle, 2005). The structure of a concept-map can be hierarchical or networked. In hierarchical concept-map, information is organized in a folder structure which consists of subfolders and looks in a tree-like structure. However, the folder and subfolder information in networked concept-map are organized at same level in a spider web-like structure. The hierarchical concept-map structure is more "linier" or logic than networked structure (Amadieu, Tricot, & Marine, 2009a).

For users, a concept-map is useful to develop a mental organization of information. The impacts of the concept-map as a navigation system on learning disorientation and performance are inconsistent. For example, Congos and Altun (2012) showed no significant difference between the effects of hypertext structure in hierarchical versus networked concept-map on disorientation. In contrast, Amadieu, Tricot, and Marine (2009b) found that participants from a networked group experienced a higher level of disorientation than participants from a hierarchical group. Those contrast findings indicate that hierarchical and networked concept-map structures are different environment. Therefore to generalize the model for predicting all types of cognitive load, the influences of control belief, learning disorientation, and emotions on specific types of cognitive load were examined across hierarchical and networked concept-map structures.

Purposes of the Study and Hypothesis

The purposes of present study were, first, to explore the prediction of control belief, learning disorientation, and academic emotions on specific types of cognitive load under two concept-map structure groups and, secondly, to explore the mediated effect of control belief and learning disorientation on extraneous, intrinsic, and germane load through academic emotions. Accordingly, hypotheses in the present study were organized as antecedents, consequences, direct effects and indirect effects.

Regarding the antecedents of academic emotions, the results were predicted that, in the hypermedia learning environment, control belief would positively predict positive emotions, but negatively predict negative emotions (H1a); and, learning disorientation would positively predict negative emotions, but negatively predict positive emotions (H1b). The consequences of academic emotions on cognitive load can be predicted that positive emotions would negatively predict extraneous load, but positively predict intrinsic and germane load (H2a); and, negative emotions would positively predict extraneous load, but negatively predict intrinsic and germane (H2b).

Concerning the direct effects of control belief and learning disorientation on cognitive load in the hypermedia learning environment, it is predicted that control belief would positively predict intrinsic and germane load, but negatively predict extraneous load (H3a); and, learning disorientation would only positively predict extraneous load (H3b). The mediated effect of academic emotions were predicted that control belief would affect extraneous load negatively, but affect intrinsic and germane load positively via positive emotions (H4a); control belief would affect extraneous load negatively, but affect intrinsic and germane load positively via negative emotions (H4b); learning disorientation would affect extraneous load positively, but affect intrinsic and germane load negatively via positive emotions (H4c); and, learning disorientation would affect extraneous load positively, but affect intrinsic and germane load negatively via negative emotions (H4d).

METHODS

Participants

Four hundred and eighty-five undergraduate students (77 males and 408 females) with an age range of 16 to 23 years (M = 18.66, SD = 0.98) were recruited on a voluntary basis to participate in the experiment. Before the experiment started, participants were assembled at Elementary Teacher Department's auditorium to collect their informed consent. All participants received a set of souvenirs for their participation. The participants were then randomly assigned to one of the two concept-map structures within hypermedia learning environment, i.e. hierarchical (245 students) and networked (240 students) groups.

Measurements

Control beliefs

To assess participants' control belief, the control of learning beliefs subscale from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, et al., 1991) was applied. It consists of 4 items ("If I study in appropriate ways, then I will be able to learn the material in hypermedia") with an 8-point scale from *not at all true of me* (0) to *very true of me* (7). The subscale is designed to assess control belief in classical learning context, then the phrase of 'in this course' is substituted to 'in hypermedia'. The Cronbach's alpha in the present study was .76.

Learning disorientation

The Perceived Disorientation Scale from Ahuja and Webster (2001) was applied to assess participants' learning disorientation in hypermedia learning environment. The scale consists of 7 items ("I felt lost") with an 8-point scale from *not at all true of me* (0) to *very true of me* (7). The Cronbach's alpha in the present study was .89.

Emotions

Participants' emotions were assessed using the Computer Emotions Scale from Kay and Loverock (2008) which has a total of 12 items with a 4-point scale, ranging from *none of the time* (0) to *all of the time* (3). The scale was applied to assess happiness (3 items) as an indicator of positive emotions, whereas sadness (2 items), anxiety (4 items) and anger (3 items) were used as indicators of negative emotions. The scale began with a general statement ("In general, when I am learning in hypermedia environment, I feel …"). Then the emotion items such as "Satisfied" were presented. The alpha coefficients in the present study were .56 for positive emotions and .85 for negative emotions. The positive emotions produced low reliability estimation because they consist of a few item (Kay & Loverock, 2008).

Cognitive load

The cognitive load was assessed using the Cognitive Load Questionnaire from Leppink, Paas, vanGog, Vleuten, and Merrienboer (2014). It consists of 13 items with an 11-point scale from *not at all the case* (0) to *completely the case* (10). The first four items measure intrinsic load ("The content of hypermedia was very complex"), the next four items assess extraneous load ("The explanations and instructions in hypermedia were very unclear") and the last five items assess germane load ("Learning with hypermedia really enhanced my understanding of the content that was covered"). The Cognitive Load Questionnaire is designed for university students and tested in classical learning context, then modification was performed by changing the phrase 'this activity' to 'hypermedia'. The alpha coefficients in the present study were .83, .89 and .81 for intrinsic, extraneous, and germane load subscales.

All scales were administered computer-based and presented in Bahasa Indonesian. Two Indonesian-English interpreter were involved in back-translation process. The first interpreter translated all scales from English to Bahasa Indonesian, then the second interpreter translated the Indonesian version of the scales to English. The discrepancies of the back-translation results were discussed and adjusted to the Bahasa Indonesian translation. The factor loading, reliability, and average variance extracted were presented at appendix.

Procedures

The experiment was conducted in four steps in group sessions for 20-30 minutes, including assessment, and involved 8-12 persons per session. First, participants were given overview of the study procedures, and were briefed about the rules of the experiment, such as the prohibition against conversations, making phone calls, and opening other computer programs. Secondly, they were asked to register as new participants by answering the demographic questions and creating a username and a password. Thirdly, they were permitted to study the hypermedia materials. In this step, participants were divided into two group, namely hierarchical and networked group. Participants from hierarchical group studied the hypermedia contents through hierarchical concept-map navigation system (see Fig 1.a), whereas participants from networked group studied hypermedia contents through networked concept-map navigation system (see Fig 1.b). Although the navigation system were different across groups, but the hypermedia contents were same for both group. Before exploring the learning material, participants were required to read the learning objectives as shown in the left-bottom corner of the navigation page. Participants had enough time to study the hypermedia content, but they generally spent about 20-25 minutes to study the hypermedia contents. The learning period ended when participants pressed the 'Responding Scale' icon. Finally, participants' control belief, learning disorientation, emotions, and cognitive load were assessed.

The sessions of experiment were conducted in a computer laboratory equipped with 33 multimedia desktop PCs with intranet and internet connections. Participants studied the hypermedia contents and responded to the scale using 17 inch monitors.

Materials

The researchers developed hypermedia learning materials with the topic of "Circulatory System" which were adopted from Microsoft Encarta Multimedia Encyclopedia (Setaro, 2008). As seen in Fig 1, there are two versions of the navigation systems for hypermedia learning materials that were developed according to Amadeu et al (2009a). They are hierarchical (Fig 1.a) and networked (Fig 1.b) concept-map structures of navigation systems. Following the concept-map structure from Amadeu et al (2009a), in the hierarchical concept-map structure, the hypermedia contents were organized in subordinate and superordinate relations of concepts (horizontal organization) as well as sequence of events (vertical organization); whereas in the networked concept-map structure, the hypermedia contents were organized in relational (i.e., they displayed relations such as causes, follows, shares elements, but the links were not labelled as such). The contents, concept titles and text sections were the same in the two conditions. The original version of Encarta Multimedia Encyclopedia was in English. It was then translated into Bahasa Indonesian. The hypermedia materials consisted of 14 nodes with 1 title box, 2793 Indonesian words, 1 animation video and 7 pictures.

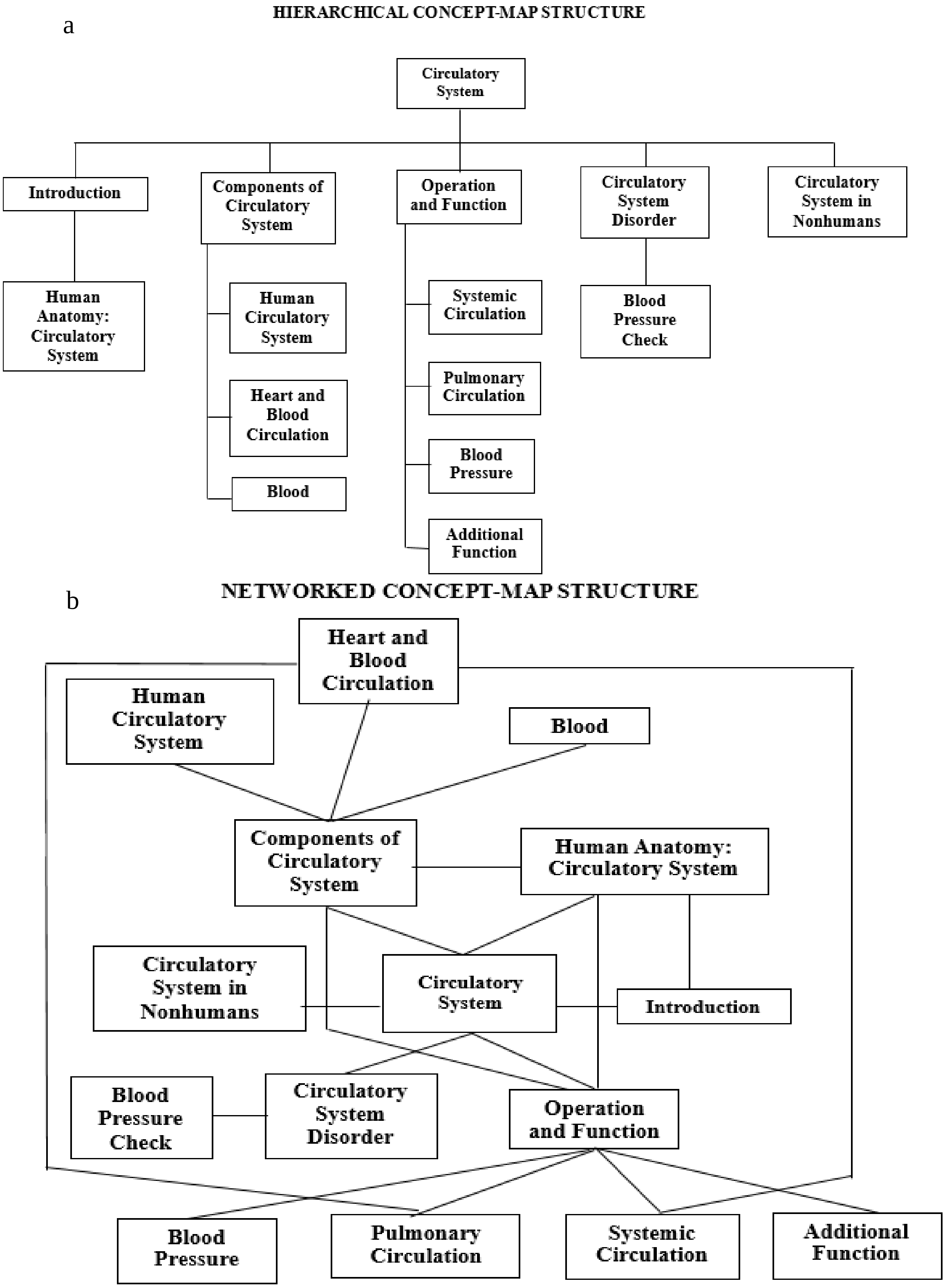


Fig 1. Hierarchical (a) and Networked (b) Concept-map Navigation System.
(Adapted from Amadeu, Tricot, & Mariné, 2009a)

RESULTS

Descriptive data

Table 1 presented the intercorrelation metric, mean and standard deviation for hierarchical and networked groups. Measures of control belief and learning disorientation were correlated with positive and negative emotions; control belief had a positive correlation with positive emotions, while learning disorientation had a negative correlation with positive emotions, but had a positive correlation with negative emotions. Positive emotions negatively correlated with extraneous load, but positively correlated with intrinsic and germane load, whereas negative emotion only positively correlated with extraneous load. Measures of control belief and learning disorientation were intercorrelated with three measures of cognitive load. Control belief positively correlated with intrinsic and germane load, but negatively correlated with extraneous load. Learning disorientation only had a positive correlation with extraneous load. The correlation directions for both hierarchical and networked groups were consistent, except the intercorrelation between control belief and extraneous load which only exists in networked group.

Table 1. Mean, Standard Deviation, and Inter-Correlation Matric of Control Belief, Learning Disorientation, Emotion, and Cognitive Load.

	LD	CLB	PE	NE	iCL	eCL	gCL
LD		.002	.20**	.58***	-.01	.43***	-.07
CLB	-.01		.40***	-.06	.30***	-.07	.50***
PE	-.139*	.41***		-.18**	.24***	-.26***	-.47***
NE	.56***	-.06	-.18**		-.02	.44***	-.12
iCL	.06	.19**	.22**	.01		.08	.50***
eCL	.42***	-.14*	-.23***	.53***	.07		-.03
gCL	-.06	.35***	.44***	-.08	.40**	-.10	
Hierarchical-	.88	4.87	2.14	.33	2.43	.92	3.19
M(SD)	(1.00)	(1.42)	(.63)	(.40)	(.60)	(.74)	(.73)
Networked-	1.05	4.92	2.25	.31	2.48	.88	3.23
M(SD)	(1.15)	(1.30)	(.48)	(.35)	(.69)	(.72)	(.70)

Note: Intercorrelations for hierarchical group (n = 245) are presented above the diagonal, and intercorrelations for networked group (n = 240) are presented below the diagonal. CLB = control belief; LD = learning disorientation; PE = positive emotion; NE = negative emotions; CL = cognitive load; * < .05; ** < .01; *** < .001

Model for Predicting Extraneous, Intrinsic and Germane Load

The models for predicting cognitive load were examined under two different concept-map structures, namely hierarchical and networked. Therefore, the multi-group invariance test was applied with a purpose to test the generalizability of the model for predicting extraneous, intrinsic and germane load across groups. The multi-group invariance test was performed in four steps following Vandenberg and Lance (2000). Data analysis was formed with AMOS version 21(IBM Corp., 2012).

Invariant model across two navigations systems

The summary results of invariance test of all models are presented in Table 2. The configural invariance metric of the model for predicting extraneous load yielded an acceptable fit (χ^2 (622) = 1185.04; χ^2/df = 1.91; CFI = .90; SRMR = .07; RMSEA (90% CI) = .04 (.04, .05)). This result indicates that the structure pattern of the model for predicting extraneous load is equal across the two navigation system groups. Because the full metric invariance test produced a χ^2 difference value of 36.68 with a degrees of freedom value of 19 and significance level at $p < .05$, the full metric invariance model was rejected. To identify those indicators that had variant factor loadings, a method suggested by Byrne (2010) was implemented. The result showed that the factor loading of item number 5 of Perceived Disorientation Scale (a7) was the source of a significant increase in the $\Delta\chi^2$ value. Relaxing the constraint of a7 produced the χ^2 difference of 25.79 with 18 degrees of freedom, which was not statistically significant at $p > .05$; hence, the partial metric invariance model was accepted. The full scalar invariance test yielded the χ^2 difference of 33.20 with 27 degrees of freedom and was statistically not significant at $p > .05$; hence, the full scalar invariance was supported. Because the full factor invariance test produced a statistically insignificant difference of χ^2 ($\Delta\chi^2$ = 11.28, Δdf = 8, $p > .05$), the factor invariance was accepted. In conclusion, the model for predicting extraneous load can be generalized across hierarchical and networked groups.

Table 2. Fit Indices for Invariant Test and χ^2 Difference Tests of Extraneous Load Model.

Test	χ^2	df	*p*	χ^2/df	CFI	SRMR	RMSEA (90% CI)	Comparative Model	$\Delta\chi^2$	Δdf	*p*	ΔCFI	Decision
Model for predicting extraneous load													
Configural invariance (Model 1)	1185.04	622	.00	1.91	.90	.07	.04 (.04, .05)	-	-	-	-	-	-
Full metric invariance (Model 2)	1221.72	641	.00	1.91	.90	.08	.04 (.04, .05)	1 – 2	36.68	19	.01	.00	Reject
Partial metric invariance (Model 3) *(a7 free)*	1210.83	640	.00	1.89	.90	.07	.04 (.04, .05)	1 – 3	25.79	18	.11	.00	Accept
Full scalar invariance (Model 4)	1244.03	667	.00	1.87	.90	.07	.04 (.04, .05)	3 – 4	33.20	27	.19	.00	Accept
Full factor invariance (Model 5)	1255.31	675	.00	1.86	.90	.08	.04 (.04, .05)	4 – 5	11.28	8	.19	.00	Accept
Model for predicting intrinsic load													
Configural invariance (Model 1)	1130.11	616	.00	1.84	.91	.08	.04 (.04, .05)	-	-	-	-	-	-
Full metric invariance (Model 2)	1161.42	635	.00	1.83	.90	.08	.04 (.04, .05)	1 – 2	31.31	19	.04	.00	Reject
Partial metric invariance (Model 3) *(a10 free)*	1156.91	634	.00	1.83	.90	.08	.04 (.04, .05)	1 – 3	26.80	18	.08	.00	Accept
Full scalar invariance (Model 4)	1188.86	661	.00	1.80	.90	.08	04 (.04, .04)	3 – 4	31.95	27	.23	.00	Accept
Full factor invariance (Model 5)	1195.30	668	.00	1.79	.90	.08	.04 (.04, .04)	4 – 5	6.45	7	.49	.00	Accept
Model for predicting germane load													
Configural invariance (Model 1)	1274.63	664	.00	1.92	.90	.08	.04 (.04, .05)	-	-	-	-	-	-
Full metric invariance (Model 2)	1314.34	683	.00	1.92	.90	.08	.04 (.04, .05)	1 – 2	39.71	19	.00	.00	Reject
Partial metric invariance (Model 3) *(a6, a10 and a18 free)*	1298.39	680	.00	1.91	.90	.08	.04 (.04, .05)	1 – 3	24.01	16	.09	.00	Accept
Full scalar invariance (Model 4)	1332.39	708	.00	1.88	.90	.08	.04 (.04, .05)	3 – 4	33.75	28	.21	.00	Accept
Full factor invariance (Model 5)	1345.82	716	.00	1.88	.90	.08	.04 (.04, .05)	4 – 5	13.43	8	.10	.00	Accept

Configural invariance (structure pattern equal); metric invariance (factor loading equal); scalar invariance (item intercept equal); factor variance invariance (structural path equal)

As seen in Table 2, the configural invariance test of the model for predicting intrinsic load yielded an acceptable fit (χ^2 (616) = 1130.11; χ^2/df = 1.84; CFI = .91; SRMR = .08; RMSEA (90% CI) = .04 (.04, .05)). However, the full metric invariance test was not supported ($\Delta\chi^2$ = 31.31, Δdf = 19, $p < .05$). Relaxing the constraints item number 5 of the Computer Emotions Scale (a10) produced an acceptable partial metric invariance model ($\Delta\chi^2$ = 26.80, Δdf = 18, $p > .05$). The full scalar metric invariance model was also accepted ($\Delta\chi^2$ = 31.95, Δdf = 27, $p > .05$). The full factor invariance tests also showed an acceptable result ($\Delta\chi^2$ = 6.45, Δdf = 7, $p > .05$). Thus, the results of multi-group invariance test showed that the model for predicting intrinsic load can be generalized across hierarchical and networked groups.

The result of the configural invariance test showed that the model for predicting germane load had acceptable fit (χ^2 (664) = 1274.63; χ^2/df = 1.92; CFI = .90; SRMR = .08; RMSEA (90% CI) = .04 (.04, .05)). The full metric invariance test was not supported ($\Delta\chi^2$ = 39.71, Δdf = 19, $p < .01$). Relaxing the constraints item number 4 of the Perceived Disorientation Scale (a6), item number 5 of the Computer Emotions Scale (a10), and item number 11 of Cognitive Load Scale (a18) yielded a non-significant difference of χ^2 ($\Delta\chi^2$ = 24.01, Δdf = 16, $p > .05$). The full scalar invariance test supported invariance across groups ($\Delta\chi^2$ = 33.75, Δdf = 28, $p > .05$). The full factor invariance test was also supported ($\Delta\chi^2$ = 13.43, Δdf = 8, $p > .05$). These results showed that the model for predicting germane load can be generalized across hierarchical and networked navigation system groups.

The structural model for predicting extraneous, intrinsic and germane load

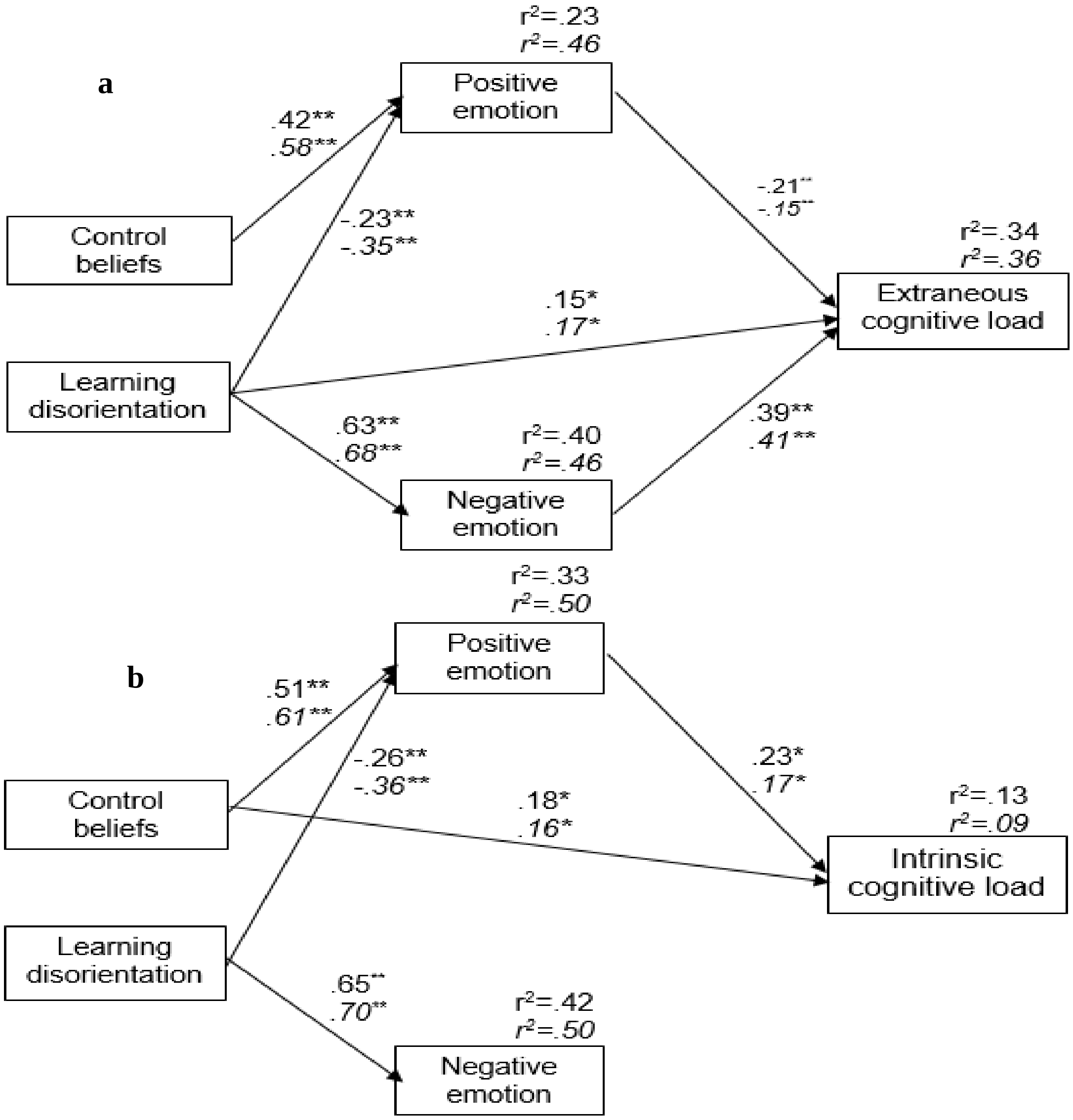
The models for predicting extraneous, intrinsic, and germane load are presented in Figs 2a, 2b, and 2c respectively. For all models, control belief consistently predicted positive emotions (hierarchical: $\beta_{extraneous}$ = .42, $\beta_{intrinsic}$ =.51, and $\beta_{germane}$ =.55, $p < .01$; networked: $\beta_{extraneous}$ = .58, $\beta_{intrinsic}$ =.61, and $\beta_{germane}$ =.60, $p < .01$), but predicted negative emotions only in the model for predicting germane load (β = -.12 and -.11, $p < .05$, for hierarchical and networked group respectively). Learning disorientation consistently had a positive association with negative emotions (hierarchical: $\beta_{extraneous}$ = .63, $\beta_{intrinsic}$ = .65, and $\beta_{germane}$ =.64, $p < .01$; networked: $\beta_{extraneous}$ = .68, $\beta_{intrinsic}$ = .70, and $\beta_{germane}$ =.69, $p < .01$) and a negative association with positive emotions (hierarchical: $\beta_{extraneous}$ = -.23, $\beta_{intrinisc}$ = -.26, and $\beta_{germane}$ = -.22, $p < .05$; networked: $\beta_{extraneous}$ = -.35, $\beta_{intrinisc}$ =-.36, and $\beta_{germane}$ =-.28, $p < .01$).

Both positive and negative emotions predicted extraneous, intrinsic, and germane load. Particularly, positive emotions appeared to lead to decreased extraneous load, but increased intrinsic and germane loads (hierarchical: $\beta_{extraneous}$ = -.21, $\beta_{intrinsic}$ = .23, and $\beta_{germane}$ = .46, $p < .01$; networked: $\beta_{extraneous}$ = -.15, $\beta_{intrinsic}$ = .17, and $\beta_{germane}$ =

.39, p < .01). However, negative emotions only predicted greater extraneous load (β = .39 and .41, p < .01, for hierarchical and networked group respectively).

Taking these findings as whole, the predictions of antecedents and consequences of academic emotions in hypermedia learning environments were mostly supported. As predicted in Hypothesis 1b and 2a, learning disorientation affected both positive and negative emotions. Then positive emotions had consequences on extraneous, intrinsic and germane loads. However, the findings that control belief predicted negative emotions only in the model for predicting germane load, and negative emotions only positively affected extraneous load provided only partial support for Hypothesis 1a and 2b.

Control belief and learning disorientation also had direct effects on extraneous, intrinsic and germane load (Fig 2a, 2b, and 2c). In particular, control belief positively predicted intrinsic and germane load (hierarchical: $\beta_{intrinsic}$ = .18, p < .05 and $\beta_{germane}$ = .28, p < .01; networked: $\beta_{intrinsic}$ = .16, p < .05 and $\beta_{germane}$ = .26, p < .01), but insignificantly predicted extraneous load. These findings partly verified Hypothesis 3a. Hypothesis 3b was also supported because learning disorientation positively predicted extraneous load in both the hierarchical and networked groups (β = .15 and .17, p < .05, respectively).



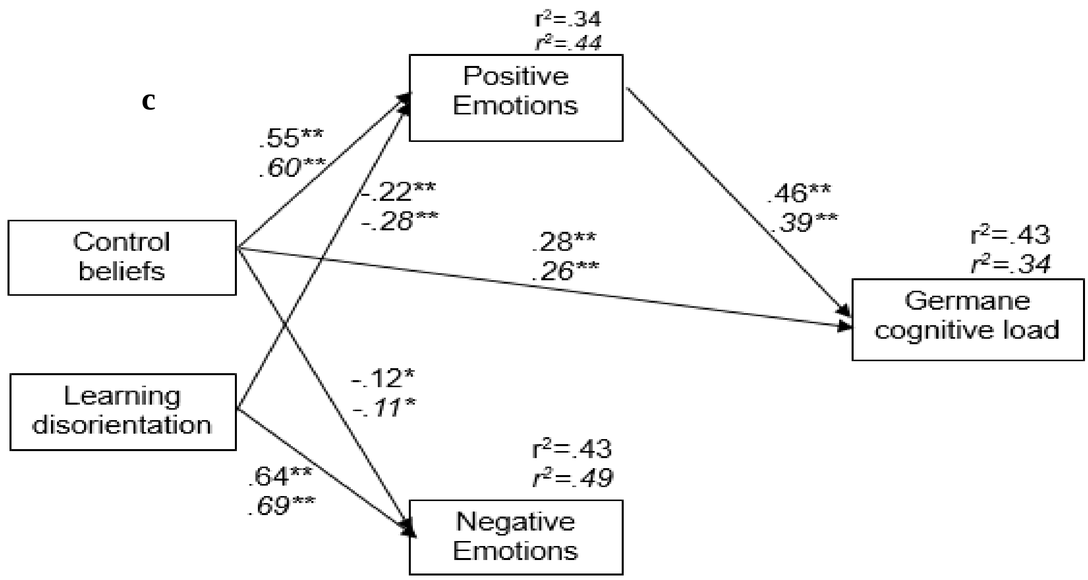


Fig 2. Invariant Model for Predicting Extraneous (a), Intrinsic (b) and Germane Cognitive Load (c) between Hierarchical and Networked Navigation System.

Note: Normal font of values (xx)= estimations of hierarchical group; Italic font of values (*xx*)= estimations of networked group; * *p* < .05; ** *p* < .01.

The Mediating Effects of Control Belief and Learning Disorientation on Cognitive Load through Academic Emotions

Due to the results of the multi-group invariance test showing that all the models were invariant across the hierarchical and networked groups, the mediation analysis was performed with all participants as a single group. The mediation analysis was performed by using bias-corrected bootstrapping to generate confidence intervals (Preacher & Hayes, 2008). The bootstrapping sampling (n = 2000) distributions of the indirect effects are produced by calculating the indirect effects in the samples. The indirect effects are estimated by using point estimates and confidence intervals (95%). The summary results of mediated analysis are presented in Table 3.

Table 3. Bootstrapped Conditional Indirect Effects of Control Belief and Learning Disorientation on All Type of Cognitive Load via Academic Emotions.

Predicted mediated effect	Observed mediated effects				
	Estimate	SE	BC 95%		
			Lower	Upper	*p*
Model for predicting extraneous load					
CB➔PE➔eCL	-.13	.06	-.27	-.02	.01
LD➔PE➔eCL	.09	.05	.02	.20	.01
LD➔NE➔eCL	.34	.15	.08	.68	.01
Model for predicting intrinsic load					
CB➔PE➔iCL	.19	.08	.06	.37	.01
LD➔PE➔iCL	-.09	.04	-.18	-.02	.01
Model for predicting germane load					
CB➔PE➔gCL	.31	.08	.18	.52	.00
LD➔PE➔gCL	-.14	.04	-.24	-.06	.00

CB: control belief; LD: learning disorientation; PE: positive emotion; NE: negative emotion; eCL: extraneous load; iCL: intrinsic load; gCL: germane load; BC = Bias-corrected of percentile point; SE = Standard Error

In the model for predicting extraneous load, control belief had a negative indirect effect on extraneous load via positive emotion (β = -.13, p < .01). There were positive indirect effects of learning disorientation on extraneous load via positive emotions (β = .09, p < .01) and negative emotions (β = .34, p < .01). Control belief and learning disorientation also had indirect effects on intrinsic and germane load. Particularly, control belief indirectly influenced intrinsic (β = .19, p < .01) and germane load (β =.31, p < .00) positively via positive emotions. Learning disorientation had a negative indirect effect on intrinsic (β = -.09, p < .01) and germane load (β = -.14, p < .00) via positive emotions. The results of mediated analysis were consistent with Hypotheses 4a and 4c, but partly supported Hypothesis 4d. Hypothesis 4b was rejected.

DISCUSSION

The association between emotions and cognitive load has been identified by Bergren, Koster, and Darakhsan (2012), Chen and Chang (2009), and Qi et al (2014). However, those studies only measured cognitive load as a single construct, they are unable to explain the effects of emotions on specific types of cognitive load. The current study found that positive and negative emotions had consequences on cognitive load. Specifically, positive emotions were associated with lower extraneous load and higher intrinsic and germane load, whereas negative emotions were associated with the higher extraneous load. Hence, the results in the present study on positive and negative emotions and three types of cognitive load are new findings. The findings on emotions and three types of cognitive load further support the analysis that intrinsic and germane cognitive load are qualitatively different from extrinsic cognitive load.

The influence of negative emotions on extraneous load can be explained by attention (Kay & Loverock, 2008) because extraneous load requires working memory capacities for processing irrelevant information. Working memory capacities need to be freed for an optimum processing of emotional information (King & Schaefer, 2010); consequently, task performance declines because working memory capacities are less devoted to processing task information. When students experience negative emotions, they tend to distract and to allocate attention and working memory capacities for processing the sources of emotional information.

Other findings indicate that control belief and positive emotions promote the use of effective strategies for processing the element interactivity of information that is embedded within extraneous, intrinsic and germane load (Sweller, 2010). These results concerning beneficial impacts replicate previous studies (Hoffman & Schraw, 2009; Reeve, Bonaccio, & Winfard, 2014; You & Kang, 2014). The high levels of control belief and positive emotions encourage implementation of effective strategies for processing relevant information in learning tasks. Control belief and positive emotions support selective attention strategies to ignore irrelevant element interactivity when facing high extraneous load. As a consequence, working memory capacity is still large enough to be devoted to handling the element interactivity in learning tasks. Under high intrinsic load, control belief and positive emotions inspire the use of effective strategies to manage the complexity of task information and to devote effective efforts to process the information, so that all element interactivity can be treated as new meaningful information. Under this circumstance, learners manage intrinsic load efficiently and optimize germane load.

The current findings support the cognitive-affective theory of learning with media (CATLM) which proposes a mediator effect of motivation and affective state on attention selection and working memory performance. Further, the indirect effect of positive emotions in the association between learning disorientation and control belief on the one hand and intrinsic and germane load on the other hand justifies the mediating role of academic emotions as outlined in the affective mediation assumption of CATLM. The impact of control belief on working memory performance will be more powerful when involving positive emotions. In contrast, the impact of learning disorientation on extraneous load will increase when involving both positive and negative emotions. Results of the present study clarify the detrimental effect of negative emotions and the valuable impact of positive emotions on working memory load.

Moreover, the findings of the present study also support three aspects of the control-value theory of academic emotions. First, the results of this study maintain the role of control belief as an antecedent for academic emotions. Specifically, the present study showed the positive influence of control belief on positive emotions in all models and the negative impact of control belief on negative emotions in a model for predicting germane load. Second, the findings of present study demonstrate the consequences of emotions on cognitive performance. Finally, the current findings shed light on the mediation role of academic emotions in strengthening the link between control belief and cognitive performance. Hence, the results of the present study support the generalization of the control-value theory of academic emotions in the hypermedia learning environment.

The present study also found that learning disorientation positively predicted extraneous load both in hierarchical and networked navigation systems. This finding supports the analysis by Amadeu et al. (2009a) showing the influence of learning disorientation on extraneous load. Because perceived disorientation is irrelevant to the learning task, learning disorientation becomes a source of extraneous load. Moreover, positive and negative emotions serve to strengthen the interrelation between learning disorientation and extraneous load. These results alert hypermedia designers about the undesirable impact of unmanaged learning disorientation for users' emotions and extraneous load.

The present study did not find any impact of navigations system on the model. In contrast with previous study from Amadeu, Tricot and Marine (2009ab) and Ethier, Hedaya, Talbot and Cadieux (2008), a finding of present study showed that there is no impact of navigation system on the model for predicting cognitive load. Specifically, present study showed that there is no any path of the model for predicting cognitive load which was moderated by navigation system. This finding reflected that the models for predicting cognitive load had an equal correlation and prediction between hierarchical and networked concept-map structure navigation system. Studies from Amadeu, Tricot and Marine (2009ab) proved that participants with networked navigation system had higher cognitive load that participants with hierarchical navigation system. The study from Ethier, Hedaya, Talbot and Cadieux (2008) found that navigation system had effect on control belief. This finding was not surprisingly because participants of present study had enough time to study the hypermedia content. With sufficient time, participants seemly succeed to adapt, organize, and learn the hypermedia contents as required in learning objectives. As a result, participants from two group of navigation system have same level of cognitive load, emotions, disorientation, and control beliefs.

CONCLUSIONS AND IMPLICATIONS

On the level of theory, the findings of the present study support the affective mediation assumption of CATLM (Moreno, 2006) and the control-value theory of academic emotions (Pekrun, 2006). The present study have succeeded to clarify the impacts of control belief and emotions on intrinsic and germane loads, and the impacts of learning disorientation and emotions on extraneous load. In the previous study, the interrelation between learning disorientation and extraneous load was lack of empirical support (Amadeu, Tricot, & Marine, 2009a). The model for predicting extraneous, intrinsic and germane cognitive load were applicable in both hierarchical and networked navigation system.

The limitation of the present study concerns to the control of participants' expertise and performance. Specifically, the present study was not control the prior knowledge and assess performance. Consequently, present study unable to show the impact of the model for predicting cognitive load on performance. Further study on motivation, learning disorientation, emotions and cognitive load need to assess participants' prior knowledge (Chen, Fan, & Macredie, 2006; Plass, Moreno, & Brunken, 2011). Moreover, present study only involved control belief as a motivational variable and two types of emotions, namely positive and negative emotions. Involving other motivation and affective factors such as self-efficacy, interest and goal orientation would be advantageous for understanding their interference with working memory load in future research.

Practical implications of this study are associated with managing cognitive load. First, the design of the hypermedia environment should lower learning disorientation with the purpose of increasing positive emotions. Secondly, the results suggest the importance of orienting users about the topics and important parts of the hypermedia design before users study hypermedia. Finally, it is important to promote learners' control belief in studying in a hypermedia learning environment.

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Appendix

Factor loading, average variance extracted and reliability

	Factor loading	Avarage Variance Extracted	Reliability
Control Beliefs (CB)			
CB 1	.77	.59	.76
CB 2	.73		
CB 3	.80		
CB 4	.78		
Learning Disorientation (LD)			
LD 1	.78	.60	.87
LD 2	.78		
LD 3	.78		
LD 4	.78		
LD 5	.73		
LD 6	.82		
LD 7	.74		
Emotions			
Happiness (Hap)			
Hap 1	.76	.54	.56
Hap 2	.80		
Hap 3	.65		
Sadness (Sad)*			
Sad 1	.85	.72	.60
Sad 2	.85		
Anxiety (Anx)*			
Anx 1	.75	.54	.71
Anx 2	.72		
Anx 3	.73		
Anx 4	.74		
Anger (Ang)*			
Ang 1	.83	.71	.78
Ang 2	.87		
Ang 3	.82		
Cognitive Load			
Intrinsic cognitive load (ICL)			
ICL 1	.88	.68	.83
ICL 2	.89		
ICL 3	.83		
ICL 4	.68		
Exraneous cognitive load (ECL)			
ECL 1	.89	.76	.89
ECL 2	.90		
ECL 3	.88		
ECL 4	.82		
Germane cognitive load (GCL)			
GCL 1	.87	.68	.81
GCL 2	.91		
GCL 3	.91		
GCL 4	.86		
GCL 5	.54		

* These types of emotions in present study were analyzed as negative emotions which have range of factor loading from .54 to .79, AVE is .47, and reliability is .85