“I can never think and play at the same time. It’s emotionally impossible.”

– From *The New Tristano*
(Lennie Tristano, 1962)

Cognitive-experiential modelling of human-computer interaction

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Outline

- Problem and proposed solution
- Research framework
- Experiential factors in HCI (and beyond)
- Rationale
- Two studies of cognitive-experiential modelling
- Conclusions

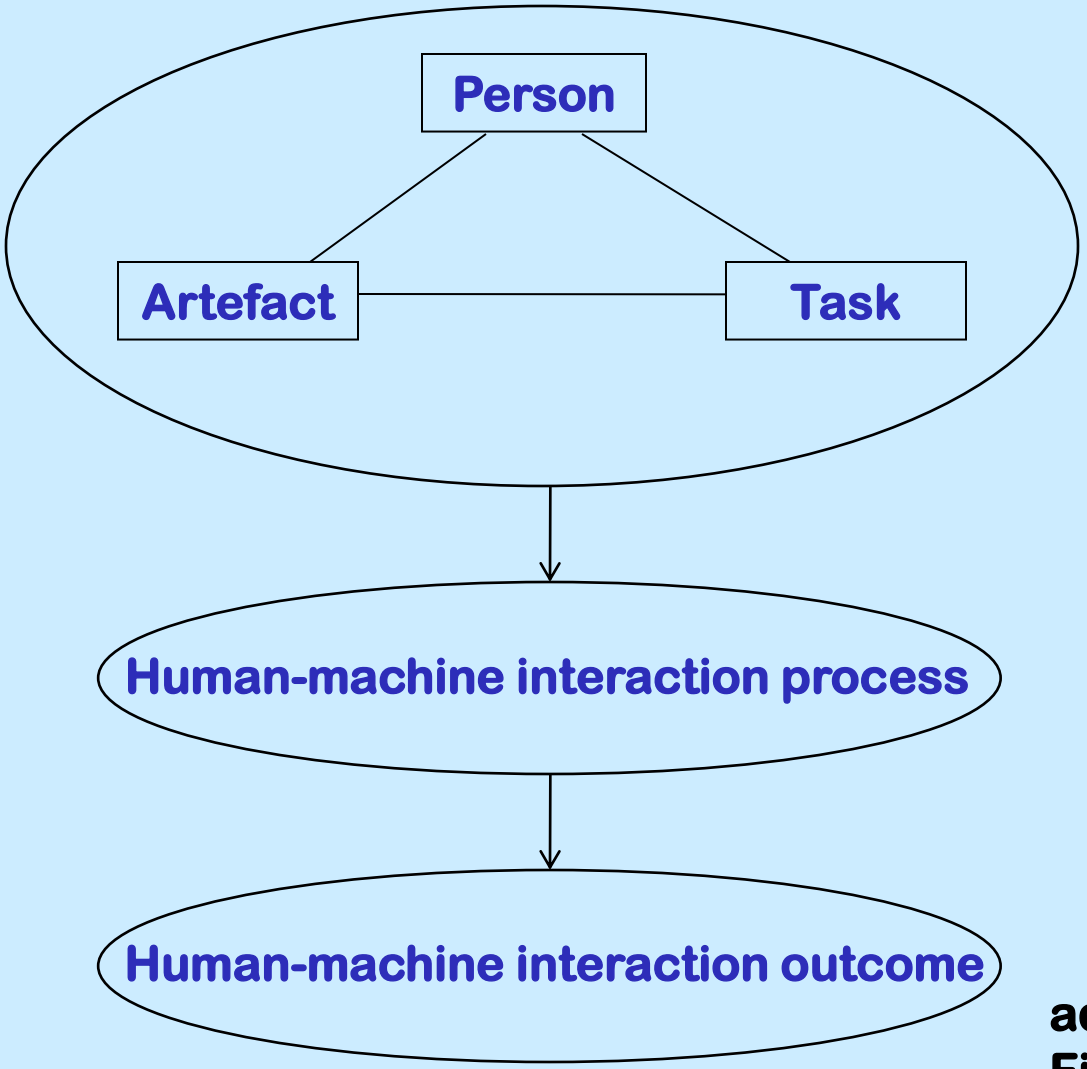
The problem

An exclusive focus on usability is not sufficient to account for users' task performance and experience

A proposed solution

Cognitive-experiential modelling of human-computer interaction

Research framework



adapted from Finneran and Zhang (2003)

The influence of the experiential (1)

- Enhanced aesthetics increases task performance under conditions of poor usability (Moshagen et al., 2009)
- Flow experience predicts performance over and above existing skills and knowledge (Engeser & Rheinberg, 2008)
- Modelling interaction experience to produce and represent HCI-knowledge and to guide system design - special issue of Interacting with Computers (Law & van Schaik, 2010)

The influence of the experiential (2)

- Experiential dynamic modelling of web navigation: 'information seek cycle' (David et al., 2007)
- David et al. highlight the role of motivation during people's interaction with an artefact, with supporting empirical evidence
- In their 'information seek cycle', as a result of the level of self-efficacy (rather than flow) from previous information-seek cycles, more challenging goals are formulated in subsequent cycles

The influence of the experiential (3)

- **'Information seek cycle' (David et al., 2007)**
  - Self-efficacy is enhanced by the successful execution of information-seeking goals in one cycle
  - Reduces the perceived difficulty of information goals in the following cycle
  - In addition, as a result of self-efficacy from previous cycles, more challenging goals are formulated in following cycles
  - Effect on cognitive task performance not studied, but - given the nature of 'virtuous circle' - enhanced performance would be expected
- **Need for an integrated approach to studying cognitive and experiential factors in human-computer interaction**

User-experience models

- Existing user/product-experience models aim to account for users' experience with artefacts, but do not address cognitive task performance
- Hassenzahl (2003, 2004)
- Thüring and Mahlke (2007)
- Desmet and Hekkert (2007)
- Hartmann et al. (2008)
- Porat and Tractinsky (in press)

Rationale

- Although experience has an effect on task performance in human-computer interaction, explicit modelling of the relationship between experience and cognitive task performance is missing
- This research aims to explicitly integrate cognitive and experiential factors in the modelling of human-computer interaction

Study 1

Schaik, P. van & Ling, J. (2012a). An experimental analysis of experiential and cognitive variables in web navigation. *Human-Computer Interaction*.

Flow experience (1)

- Human-machine interaction process: experiential component (including flow) and cognitive component (including task performance)
- 'Holistic sensation that people feel when they act with total involvement' (Csikszentmihalyi, 1990, p. 477)
- Nine dimensions of flow distinguished and measurement instruments developed (e.g. Jackson & Marsh, 1996); see also Pace (2004)
- Not a matter of 'all or nothing' - can experience a degree of flow on each dimension

Dimensions of flow experience (Jackson & March 1996)

Dimension	Description
Balance of challenge and skill	"The person perceives a balance between the challenges of a situation and one's skills, with both operating at a personally high level." (p. 18)
Goal clarity	"Goals in the activity are clearly defined (...), giving the person in flow a strong sense of what he or she is going to do." (p. 19)
Feedback	"Immediate and clear feedback is received, usually from the activity itself, allowing the person to know he or she is succeeding in the set goal." (p. 19)
Concentration	"Total concentration on the task at hand occurs when in flow" (p. 19)
Control	"A sense of exercising control is experienced, without the person actively trying to exert control." (p. 19)
Mergence of action and awareness	"The flow activity is so deep that it becomes spontaneous or automatic." (p. 18)
Loss of self-consciousness	"Concern for the self disappears during flow as the person becomes one with the activity." (p. 19)
Transformation of time	"Time alters perceptibly, either slowing down or speeding up" (p. 19)
Autotelic experience	"Intrinsically rewarding experience. An activity is autotelic if it is done for its own sake, with no expectation of some future reward or benefit." (p. 20)

Artefact - web site complexity

- **Task difficulty increases as a function of**
  - page complexity in terms of the number of navigation choices on a web page (Gwidzka & Spence, 2006)
  - structural complexity (Guo & Poole, 2009)
- **The greater the number of links per page, the lower success rate (Blackmon et al., 2002)**
- **As artefact complexity increases, the balance between challenge and skill will be negatively affected and flow experience will decrease (Guo & Poole, 2009)**
- ***Hypothesis 1a/b/c:* artefact complexity (page complexity) has a negative effect on the quality of task performance, flow experience and task outcome**

Task - task complexity

- **Task complexity (path length) has a negative effect on the quality of task performance (Gwizdka & Spence, 2006; van Oostendorp, Madrid & Puerta Melguizo; 2009)**
- **Possible mechanisms:**
  - increasing probability of (link) selection error with path length
  - increasing probability of error in relevance judgement (of content) with path length
- ***Hypothesis 2a/b/c:*** **task complexity (path length) has a negative effect on the quality of task performance, flow experience and task outcome**

Person - intrinsic motivation (1)

- **Intrinsic motivation as an individual-difference variable in web navigation**
  - disposition to engage in actions toward pursuits "internal to the self, such as personal interest, enjoyment, and learning": *intrinsic motivation*
  - "external to the self, such as tangible rewards, interpersonal status, and the dictates of others": *extrinsic motivation* (Hirschfeld et al., 2008, p. 155)
- **Positive predictor of**
  - flow experience in golf (Oh, 2001) and in athletics (Stavrou, 2008)
  - Task outcome in academic learning (Hirschfeld et al., 2008) and school learning (Vansteenkiste et al., 2008)

Person - intrinsic motivation (2)

Theoretical accounts (Zapata-Phelan et al., 2009)

- Activity, concentration, initiative, resilience and flexibility can increase, as a result, enhancing task performance
- Intrinsic motivation has a stronger effect than external motivation on the persistence of effort, which has a strong effect on task performance
- In the domain of employment, internal (work) motivation is expected to have a positive effect on the quality of task performance
- Intrinsically motivated individuals (or individual with an 'autotelic' personality) are those who engage in activities for the sake of the activities rather than in order to achieve some external goal. Therefore, these individuals should experience a higher level of flow experience, as confirmed by Asakawa (2004)

- ***Hypothesis 3a/b/c:*** **intrinsic motivation has a positive effect on the quality of task performance, flow experience and task outcome**

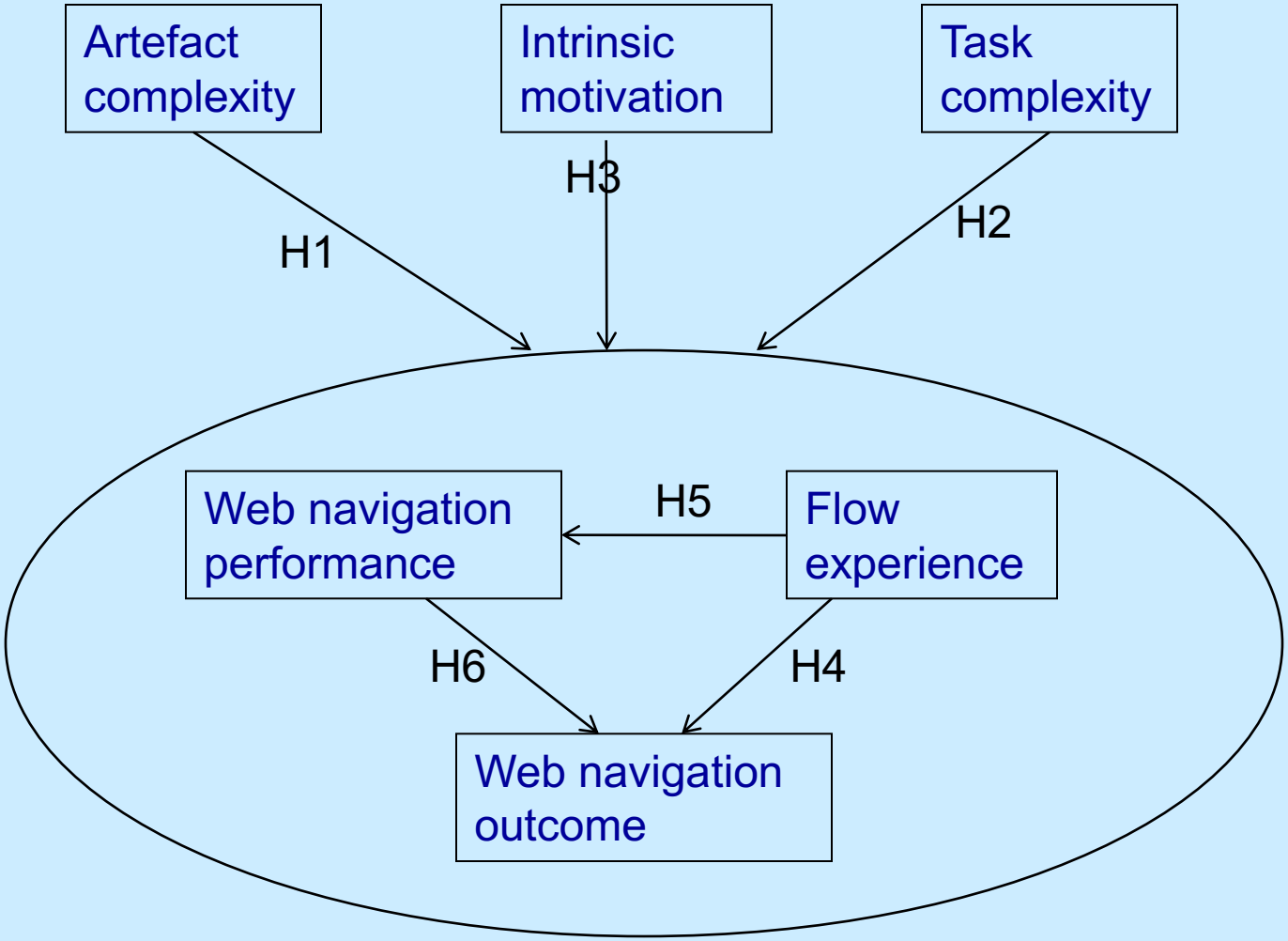
Flow experience (2)

- **Flow is an independent positive predictor of task outcome in**
  - computer-game playing (Murphy et al., 2008)
  - mathematics performance (Heine, 1997; Engeser & Rheinberg, 2008),
  - foreign-language performance (Engeser & Rheinberg, 2008)
  - computer-based statistics performance (Vollmeyer & Imhof, 2007)
- **Pathways for the positive effect of flow on performance outcome (Engeser & Rheinberg, 2008)**
  - Flow is considered to be a 'highly functional state'; therefore, should promote performance
  - Flow is a driver of motivation for continued activity; leads people to select higher challenges in order to experience flow again
- ***Hypothesis 4:*** **flow experience has a positive effect on task outcome, with the effects of artefact complexity, task complexity and intrinsic motivation held constant**

Flow experience (3)

- Given the motivating character of flow to continue task performance, the quality of task performance is a likely mediator
- Thus, flow experience has a positive effect on the quality of task performance and, thereby, a positive (indirect) effect on task outcome
- *Hypothesis 5:* flow experience has a positive effect on the quality of task performance, with the effects of artefact complexity, task complexity and intrinsic motivation held constant
- *Hypothesis 6:* the quality of task performance has a positive effect on task outcome, with the effects of artefact complexity, task complexity, intrinsic motivation and flow held constant

Research model



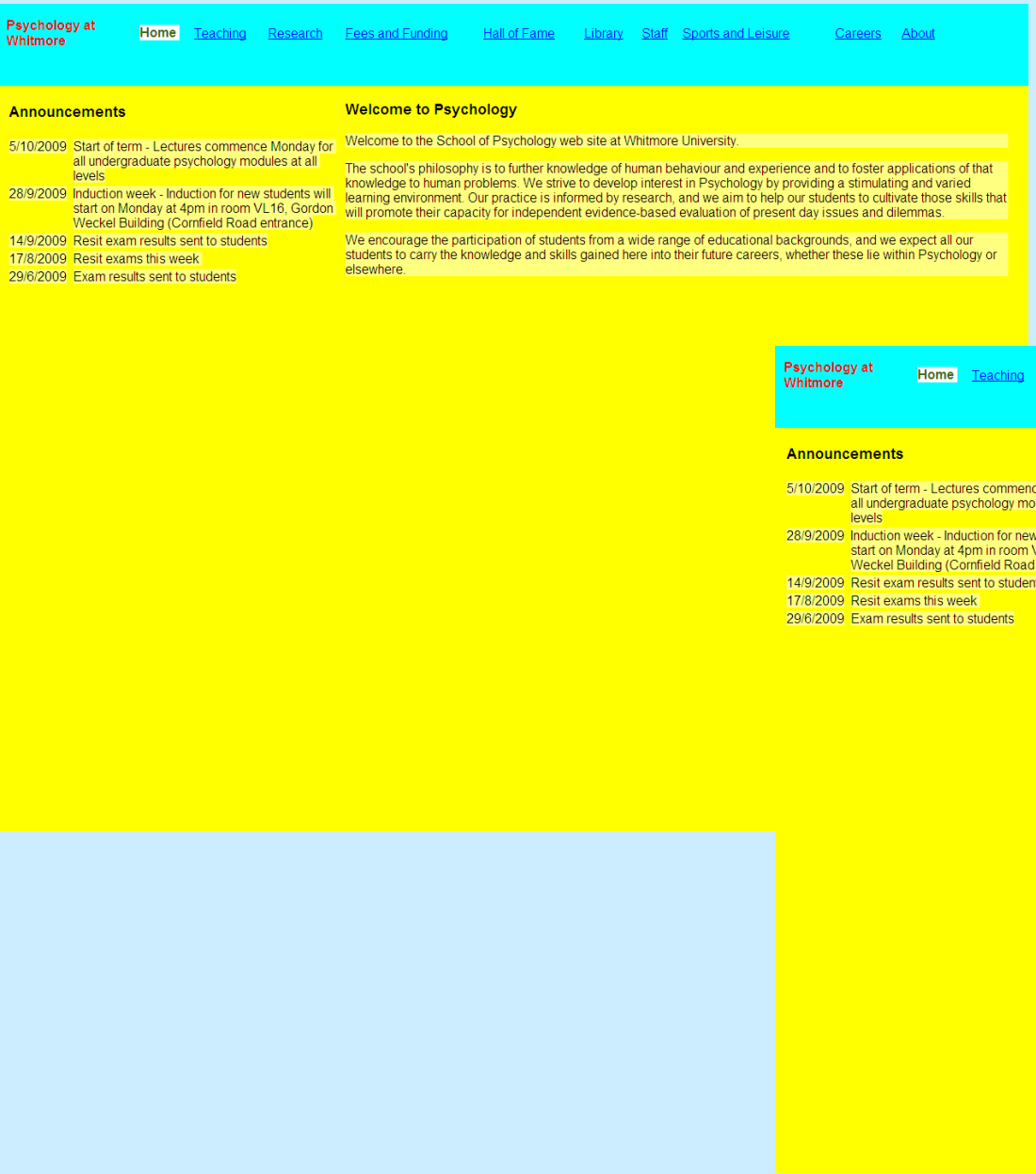
Experiment

- **Aim**

  Demonstrate the need for an integrated approach (including cognitive and experiential factors in human-computer interaction) to modelling web navigation

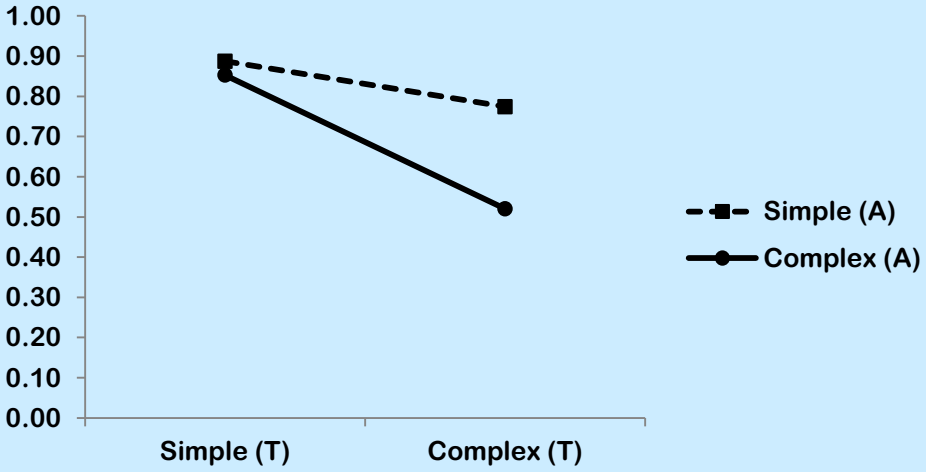
- **Method**
  - Test hypotheses, using a computer-controlled experiment
  - Artefact complexity (low or high) and task complexity (path length - low or high) manipulated
  - Test-users' intrinsic motivation measured as an individual-difference variable
  - Series of information retrieval tasks - information-oriented realistic mock intranet site
  - Task performance, flow experience (Jackson & Marsh, 1996) and task outcome measured
  - Participants: 114 undergraduate psychology students
  - Data analysis: partial-least squares (PLS) path modelling

Web site versions

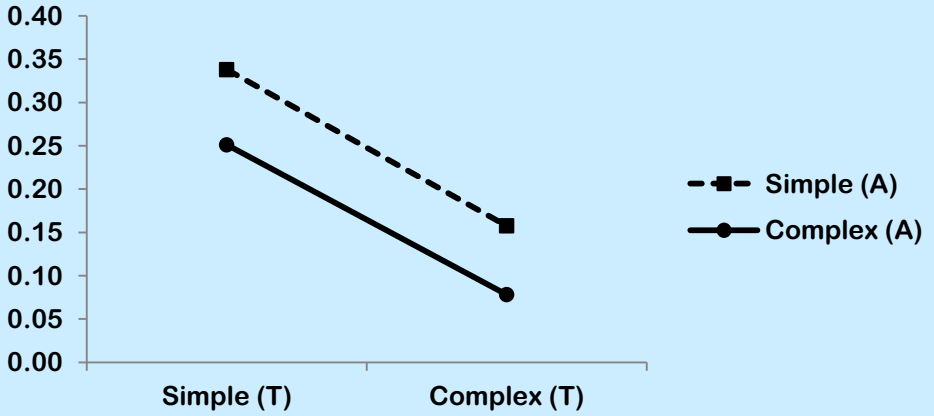


Results - descriptives (1)

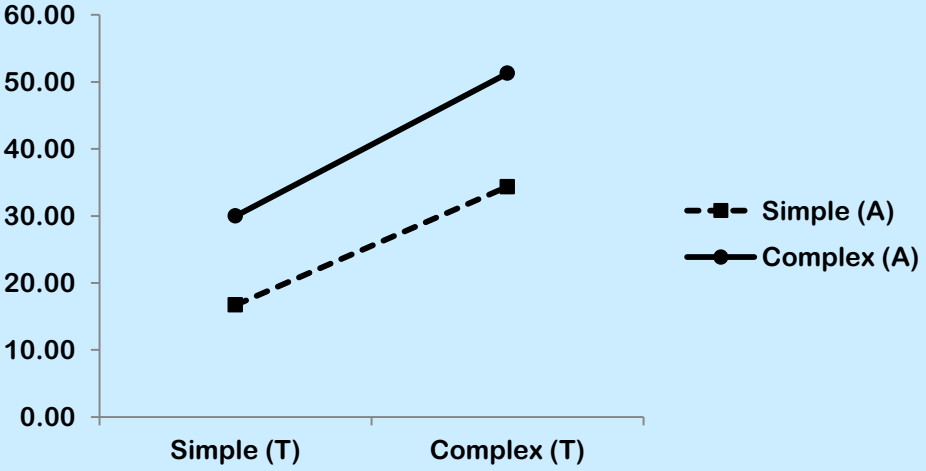
Proportion correctly completed



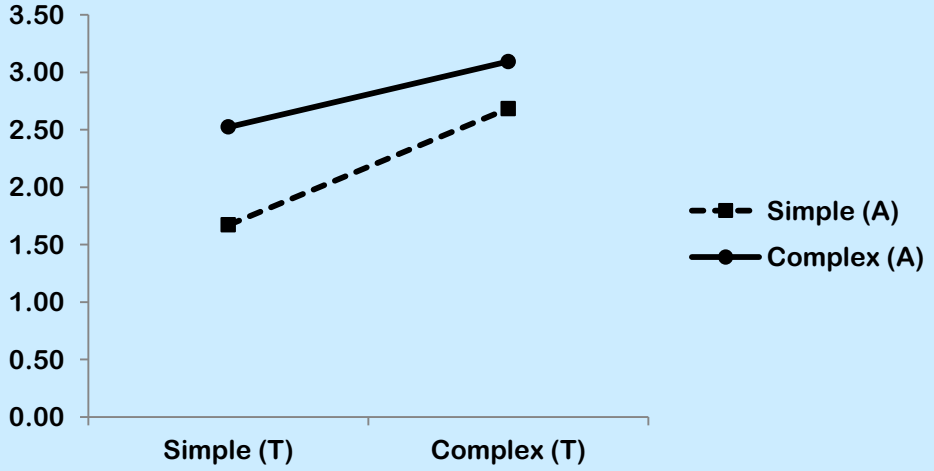
Proportion correct relative to total



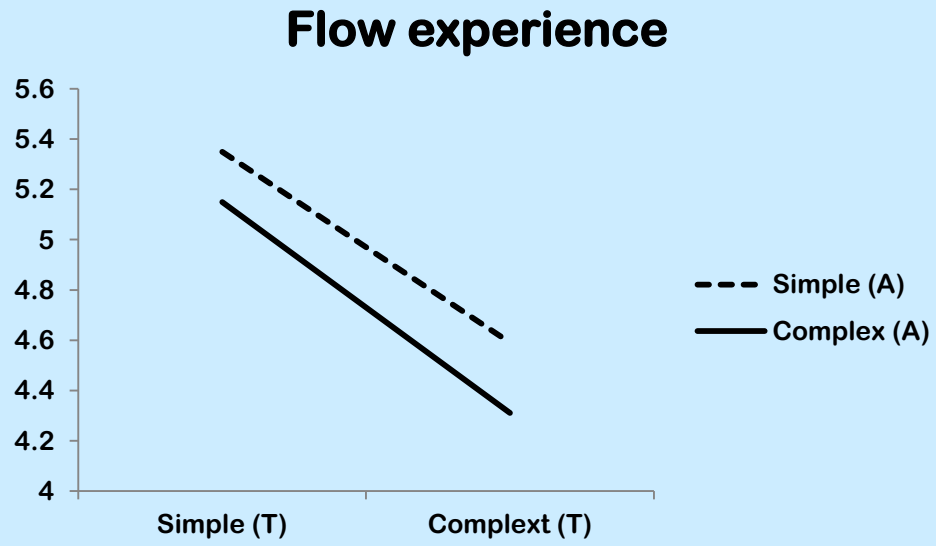
Work load (SMEQ)



Disorientation

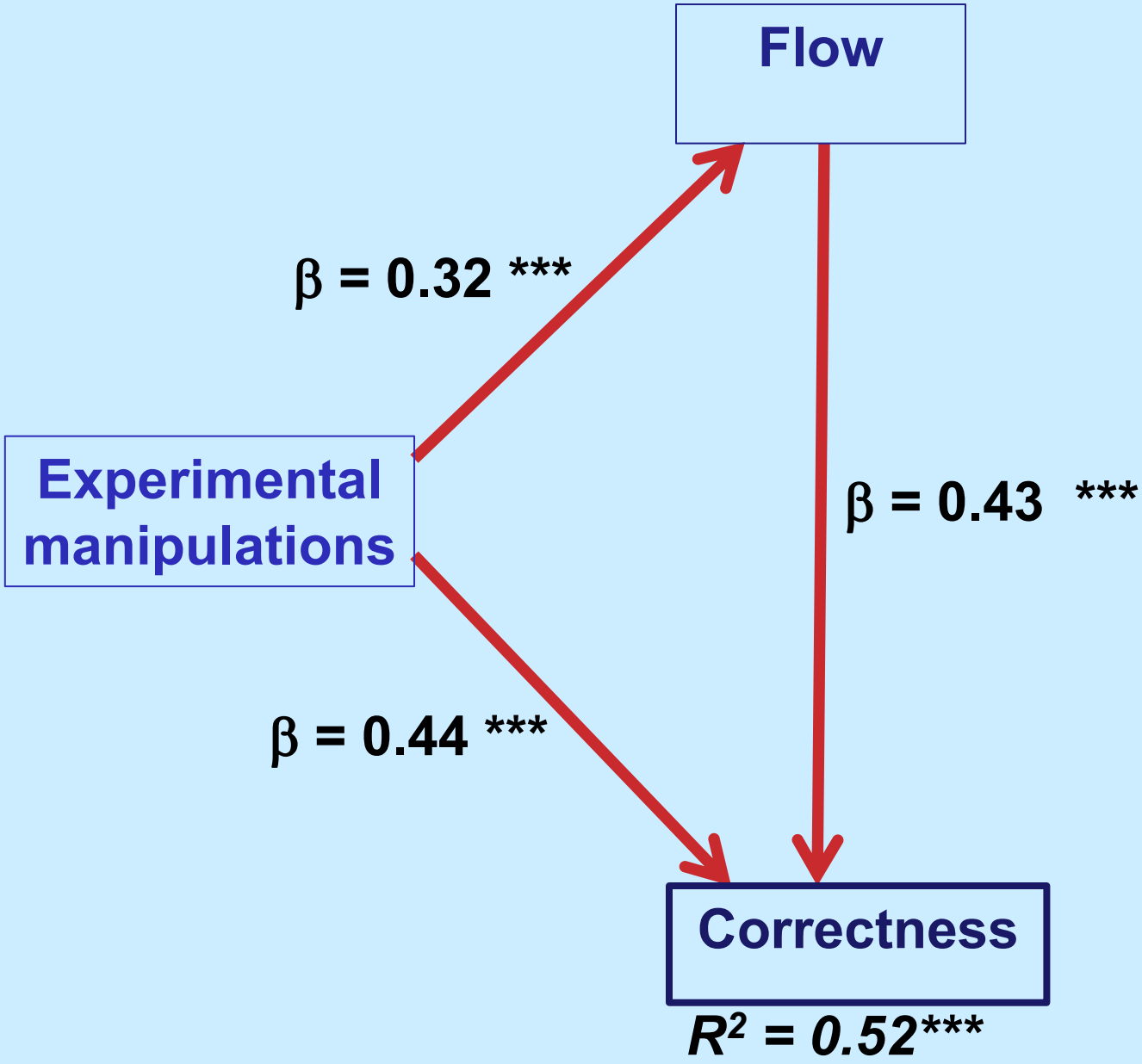


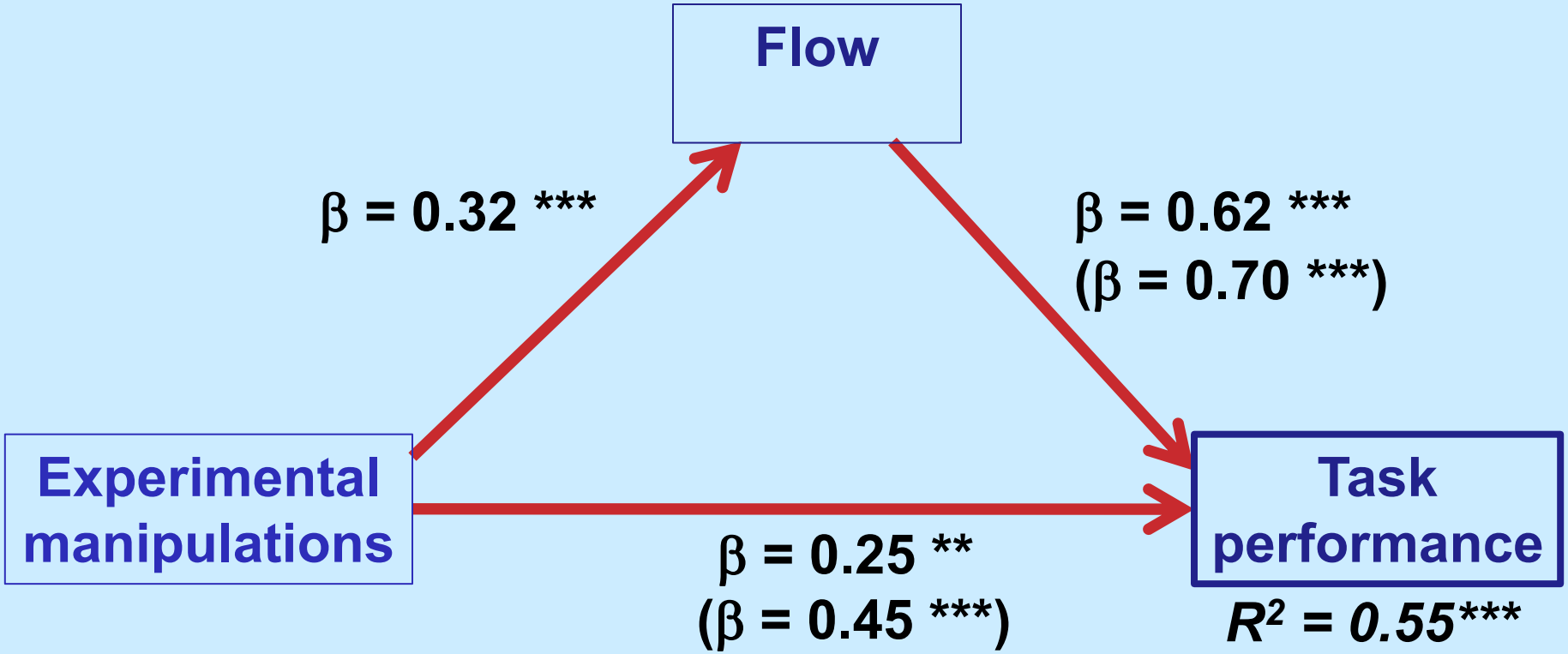
Results - descriptives (2)

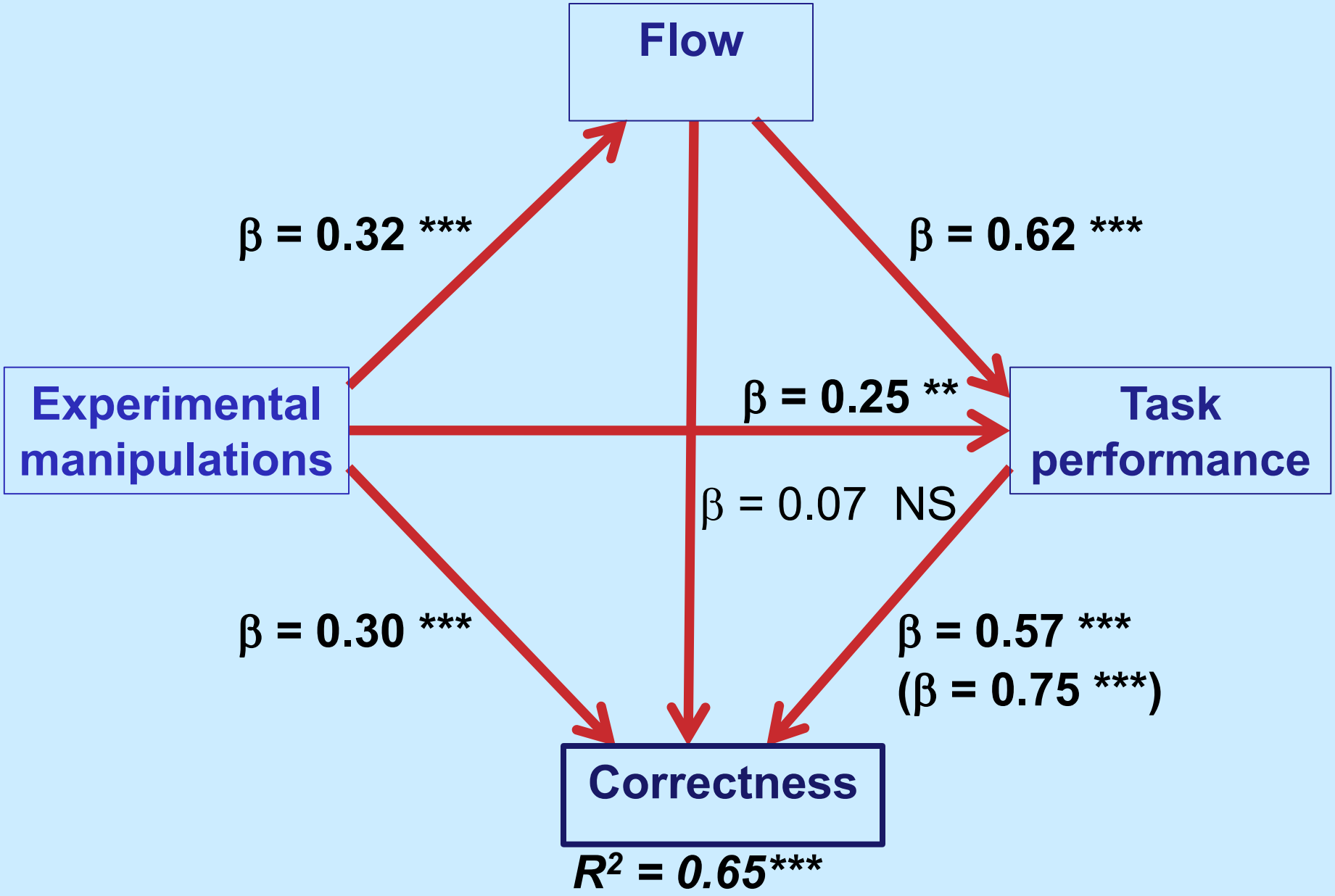


The effects of experimental manipulations, flow and task performance on task outcome

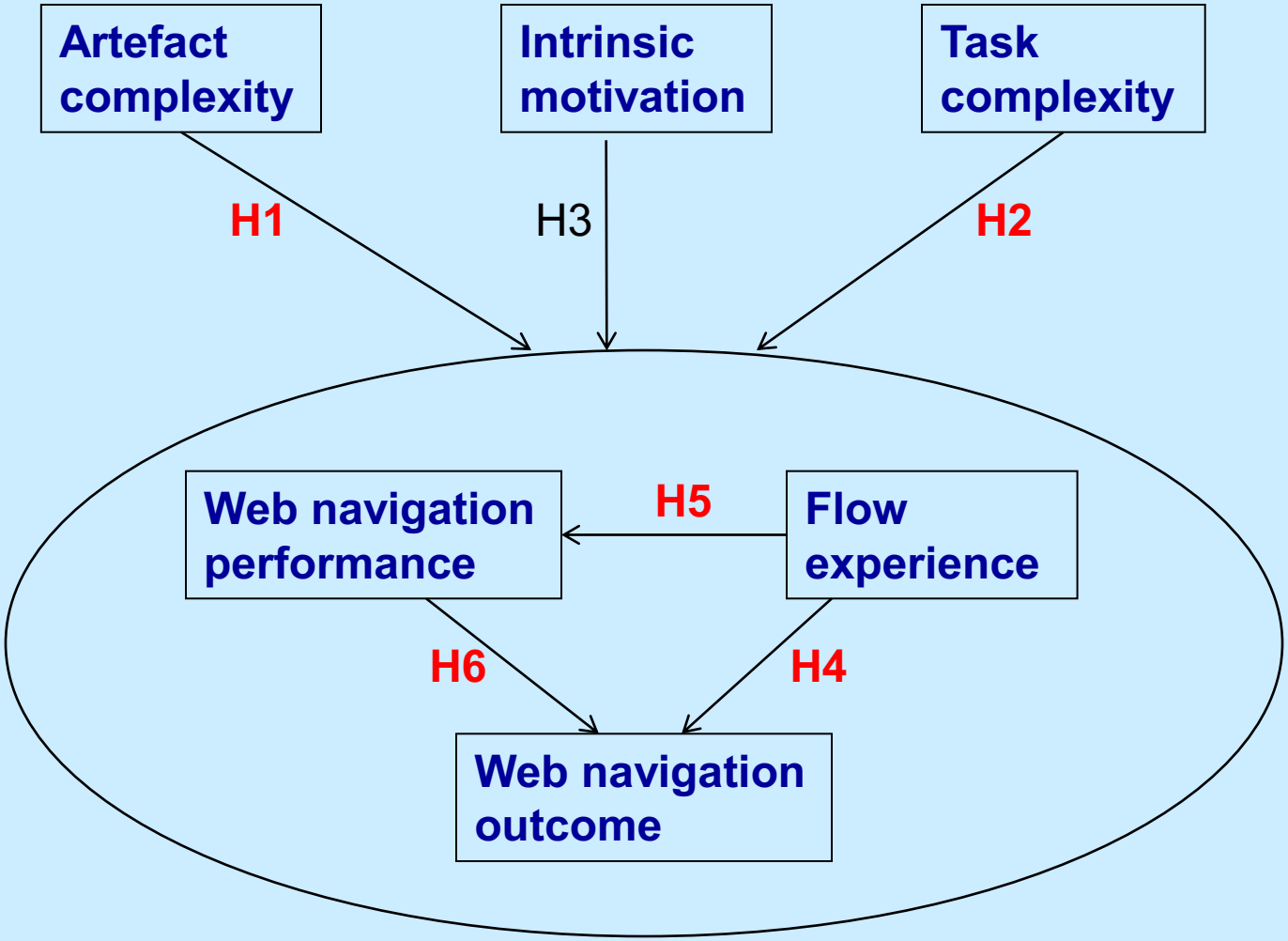
- Experimental manipulations: combinations of site complexity and task complexity
- Task performance: disorientation and work load
- Correctness: percentage of tasks completed correctly
- Figures in brackets: total effect of antecedents on consequents
- ** $p < 0.01$. *** $p < 0.001$.


Flow
β = 0.32 ***
Experimental manipulations
β = 0.43 ***
β = 0.44 ***
Correctness
R² = 0.52***


Flow
β = 0.32 ***
β = 0.62 ***
(β = 0.70 ***)
Experimental manipulations
Task performance
β = 0.25 **
(β = 0.45 ***)
$R^2 = 0.55$***


Flow
β = 0.32 ***
β = 0.62 ***
Experimental manipulations
β = 0.25 **
Task performance
β = 0.07 NS
β = 0.30 ***
β = 0.57 ***
(β = 0.75 ***)
Correctness
R² = 0.65***

Summary


Artefact complexity
Intrinsic motivation
Task complexity
H1
H3
H2
Web navigation performance
H5
Flow experience
H6
H4
Web navigation outcome

Conclusion

- **Aim**

  Evidence for the need for an integrated approach (including cognitive and experiential factors in human-computer interaction) to modelling web navigation

- **Supporting findings**
  - Within the framework of the PAT model, cognitive and experiential factors, together, do indeed influence task outcomes in web navigation
  - In particular, artefact complexity and task complexity have an effect on task performance, flow and task outcome *(Hypotheses 1-2)*, but intrinsic motivation does not *(Hypothesis 3)*
  - Flow is a partial mediator of the effect of site- and task complexity on task performance *(Hypotheses 1, 2, 5)*
  - Task performance is a complete mediator of the effect of flow on task outcome *(Hypotheses 4-6)*

Study 2

Schaik, P. van & Ling, J. (2012b, under review). A cognitive-experiential approach to modelling web navigation.

Staged model of flow

- **Preconditions of flow: attention-enhancing component of flow**

  Challenge/skill balance, goal clarity, feedback

- **Flow proper: motivational component of flow**

  Concentration, control, action-awareness mergence, transcendence of self, transformation of time, autotelic experience

Guo and Poole (2009)

- **Effect of artefact complexity on flow mediated by preconditions of flow**
- **Limitations**
  - Complexity not experimentally controlled
  - Perceived complexity analysed rather than actual complexity
  - Antecedents, but not consequents, of flow studied

van Schaik and Ling (2012a)

- **Flow is a partial mediator of the effect of experimental manipulations on task performance**
- **Task performance is a full mediator of the effect of flow on task outcome**
- **Limitations**
  - Modelling of flow experience undifferentiated – no distinction between preconditions and flow proper
  - Measurement of flow not specific to HCI
  - Ad-hoc higher-order measure of flow
  - Single measure of task outcome

Aim

Clarify the relationship between experience and task outcome

- with a staged model of flow experience
- addressing limitations of previous research

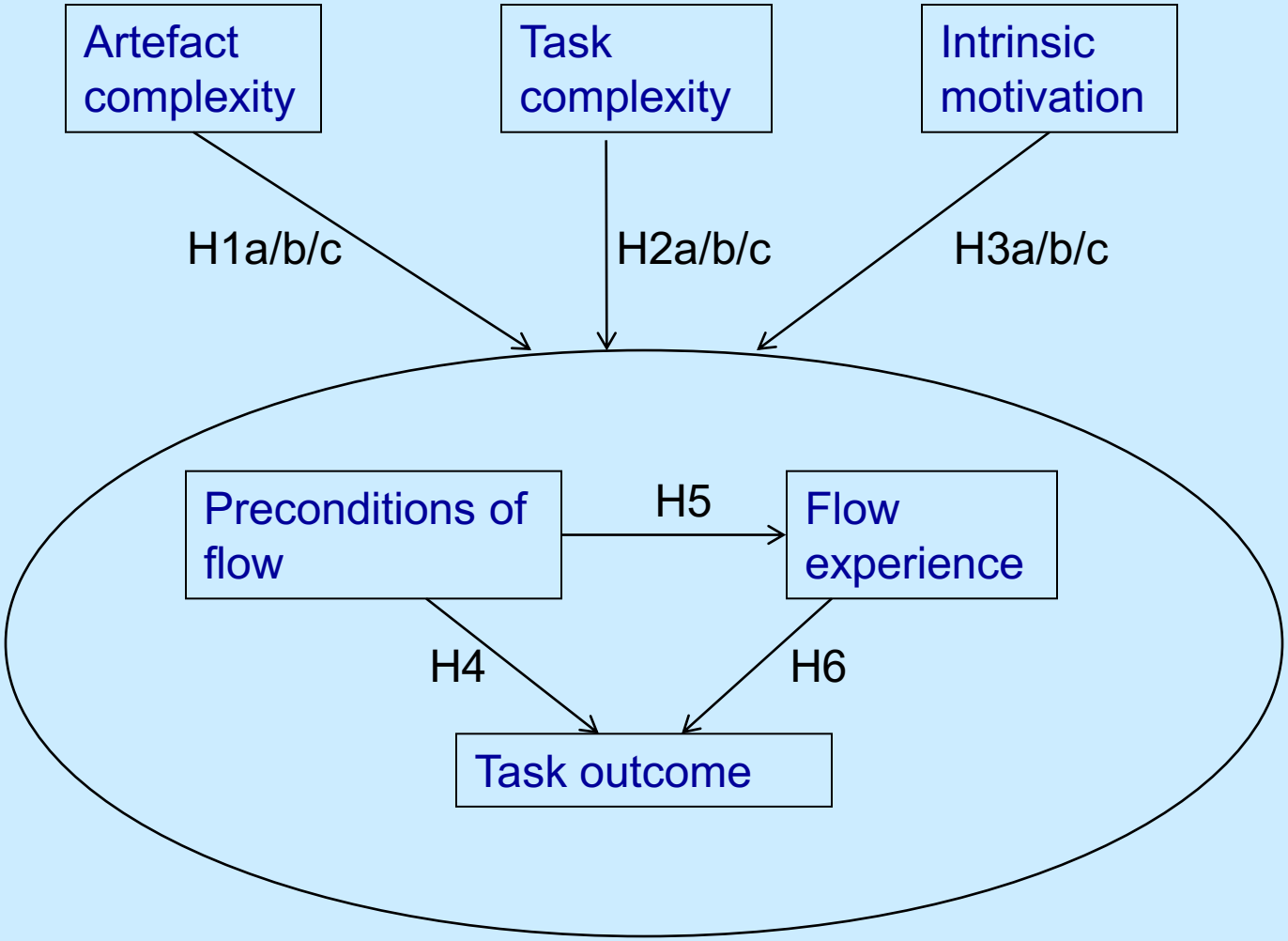
Hypotheses (continuing)

- H1a/b/c: artefact complexity has a negative effect on task outcome/preconditions/flow proper
- H2a/b/c: task complexity has a negative effect on task outcome/preconditions/flow proper
- H3a/b/c: intrinsic motivation has a positive effect on task outcome/preconditions/flow proper

Hypotheses (continued)

- H4: preconditions has a positive effect on task outcome with PAT variables held constant
- H5: preconditions has a positive effect on flow proper with PAT variables held constant
- H6: flow proper has a positive effect on task outcome with PAT variables and preconditions held constant

Research model

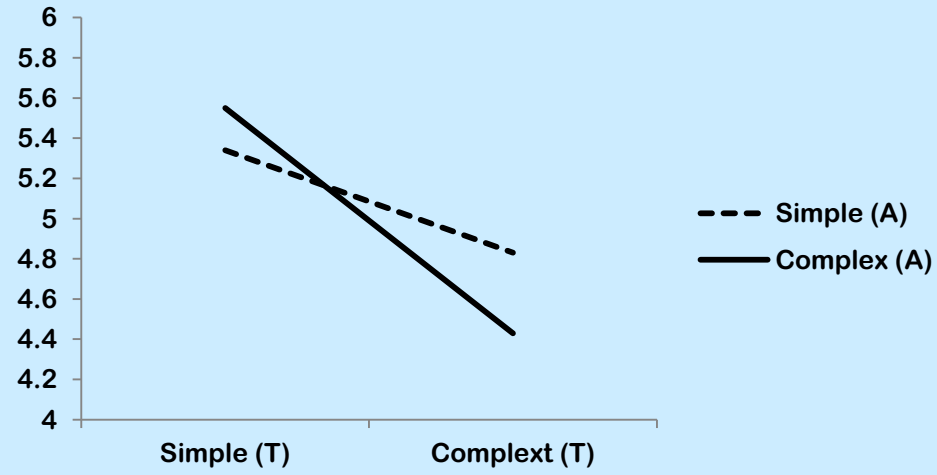


Experiment

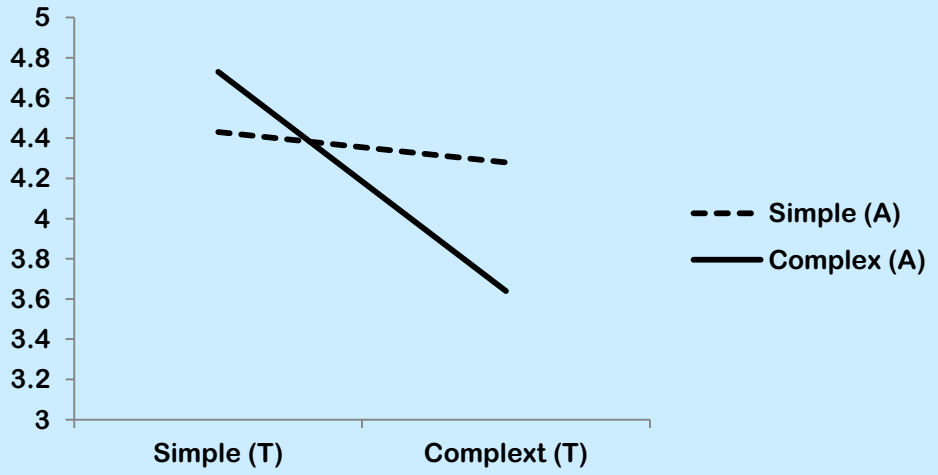
- As in van Schaik and Ling (2012a), but
- Modelling of flow experience differentiated: both preconditions and flow proper
- Measurement of flow specific to HCI (Guo & Poole, 2009)
- Theory-based higher-order measure of flow
- Multiple measures of task outcome
- N = 127

Results - descriptives

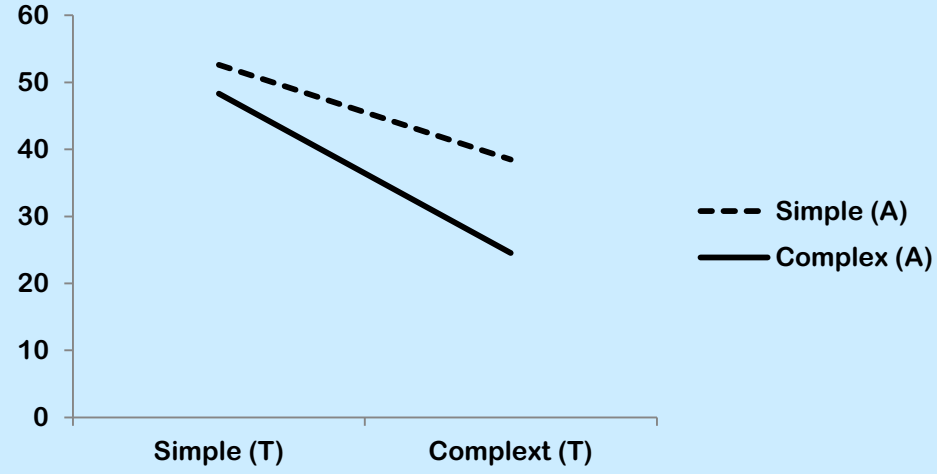
Preconditions of flow



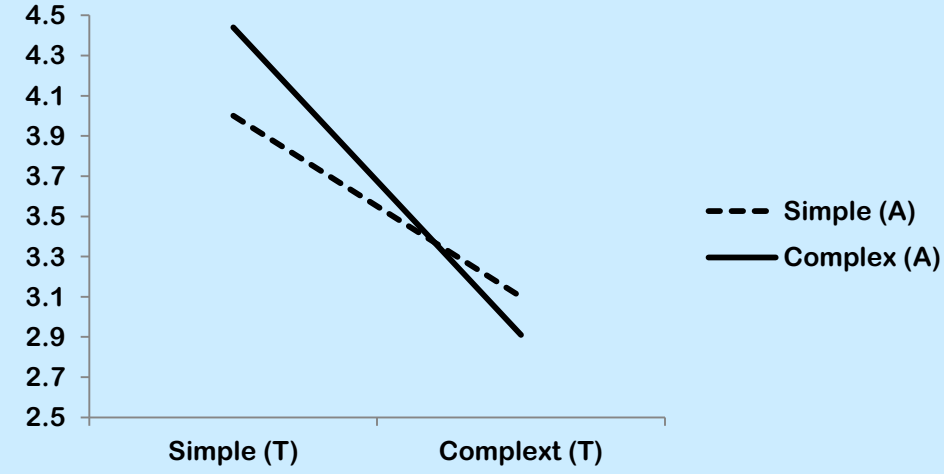
Flow experience



Task outcome

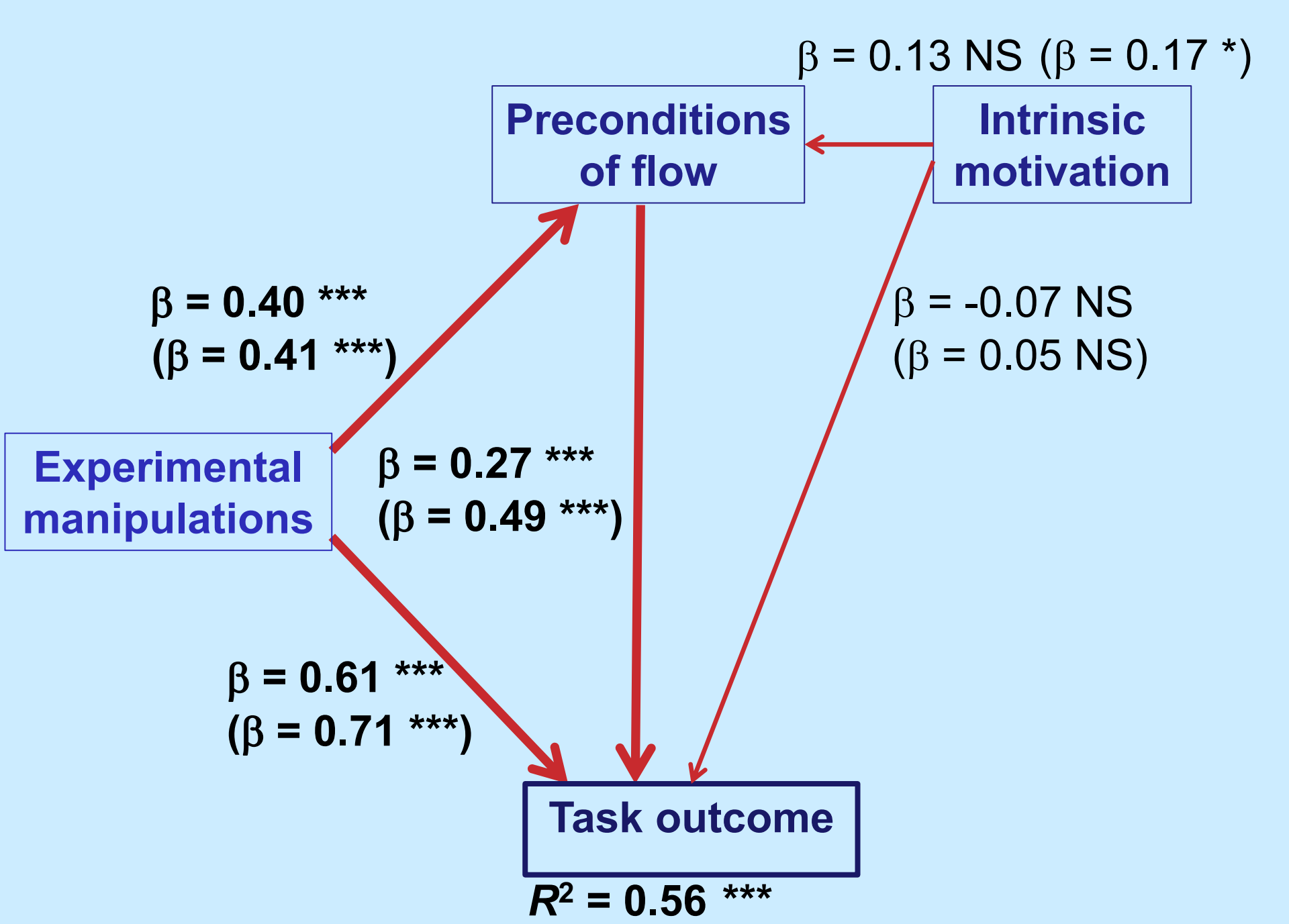


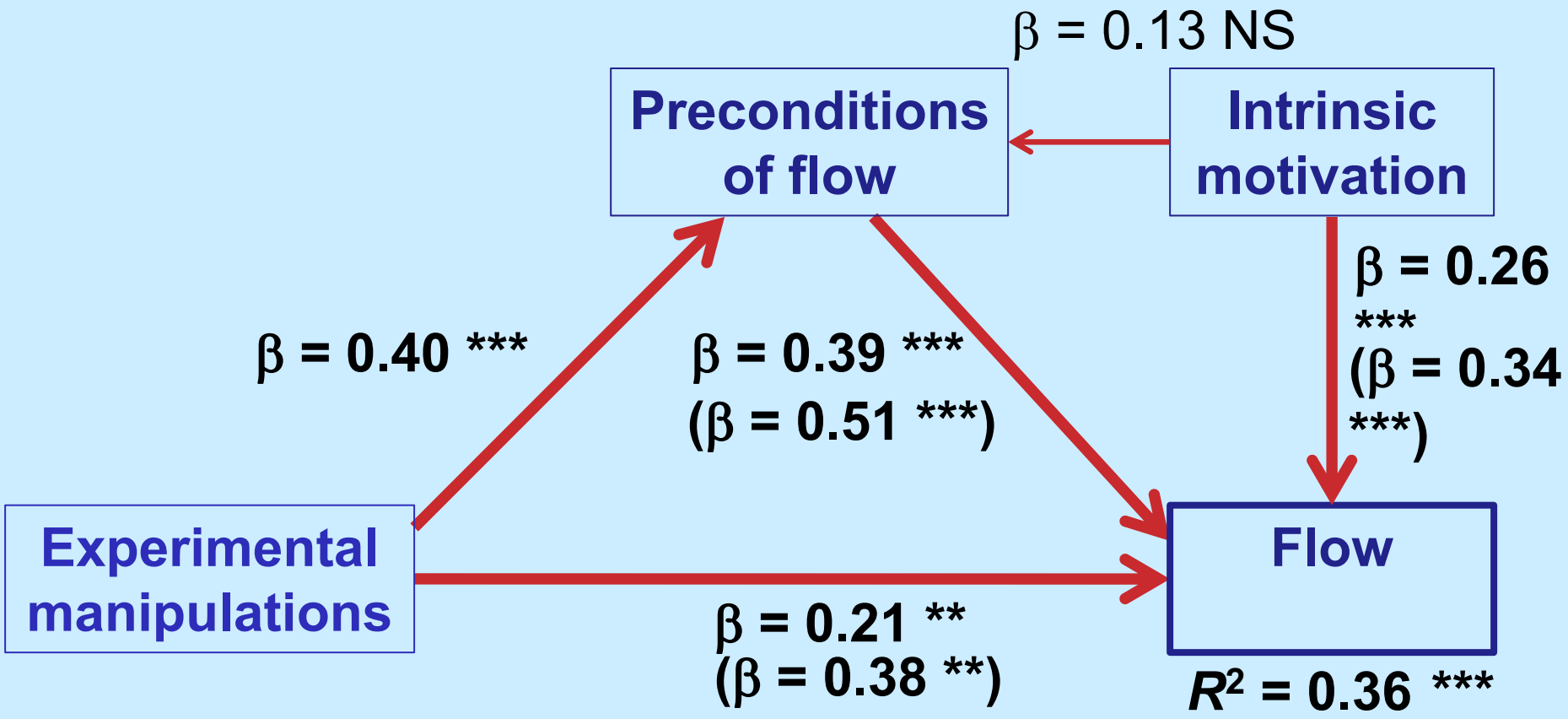
Goodness

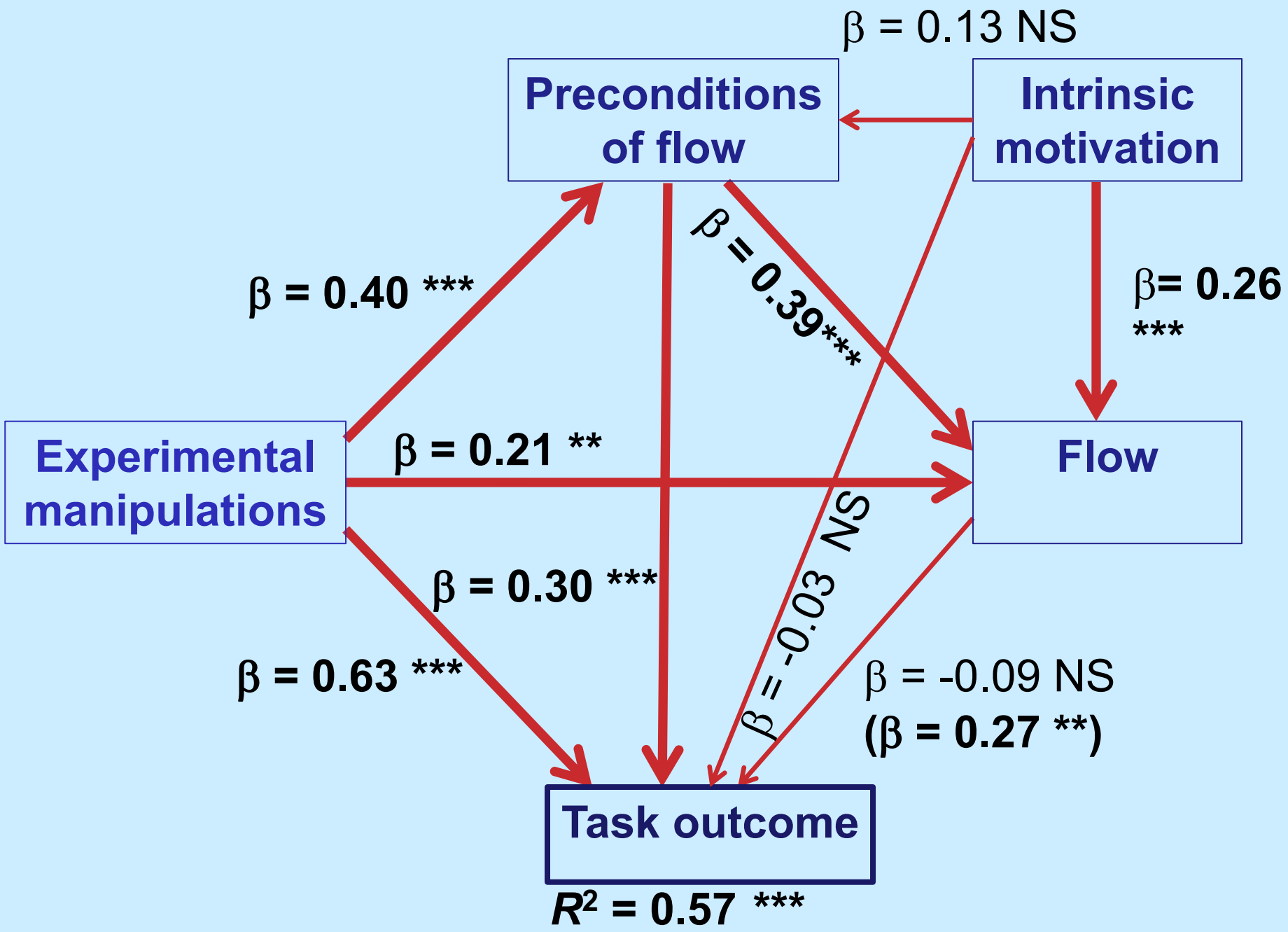


The effects of experimental manipulations, intrinsic motivation, preconditions and flow on task outcome

- Experimental manipulations: combinations of the manipulations of site complexity and task complexity
- Figures in brackets: total effect of antecedents on consequents
- * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

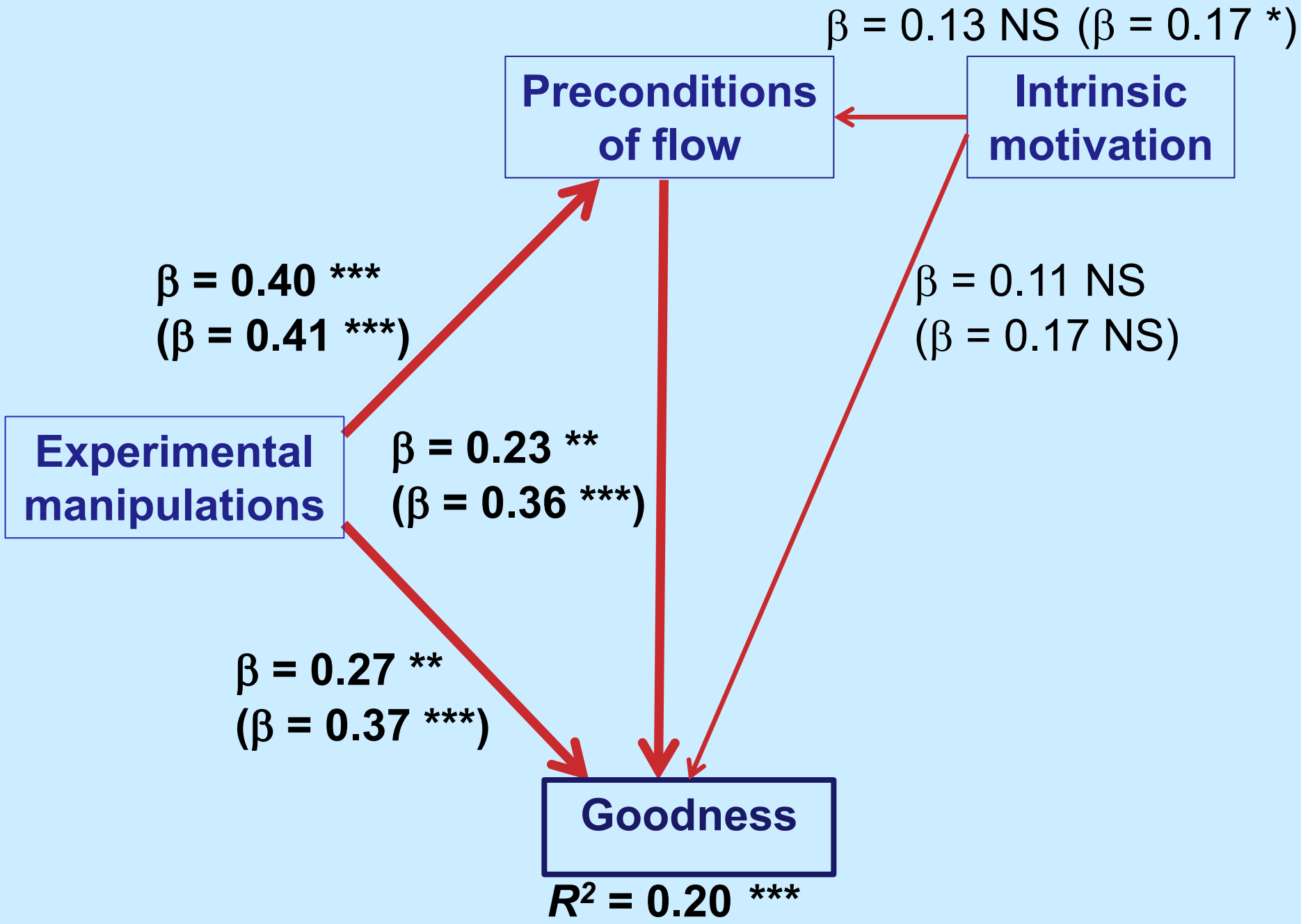

β = 0.13 NS (β = 0.17 *)
Preconditions of flow
Intrinsic motivation
β = 0.40 ***
(β = 0.41 ***)
β = -0.07 NS
(β = 0.05 NS)
Experimental manipulations
β = 0.27 ***
(β = 0.49 ***)
β = 0.61 ***
(β = 0.71 ***)
Task outcome
R² = 0.56 ***

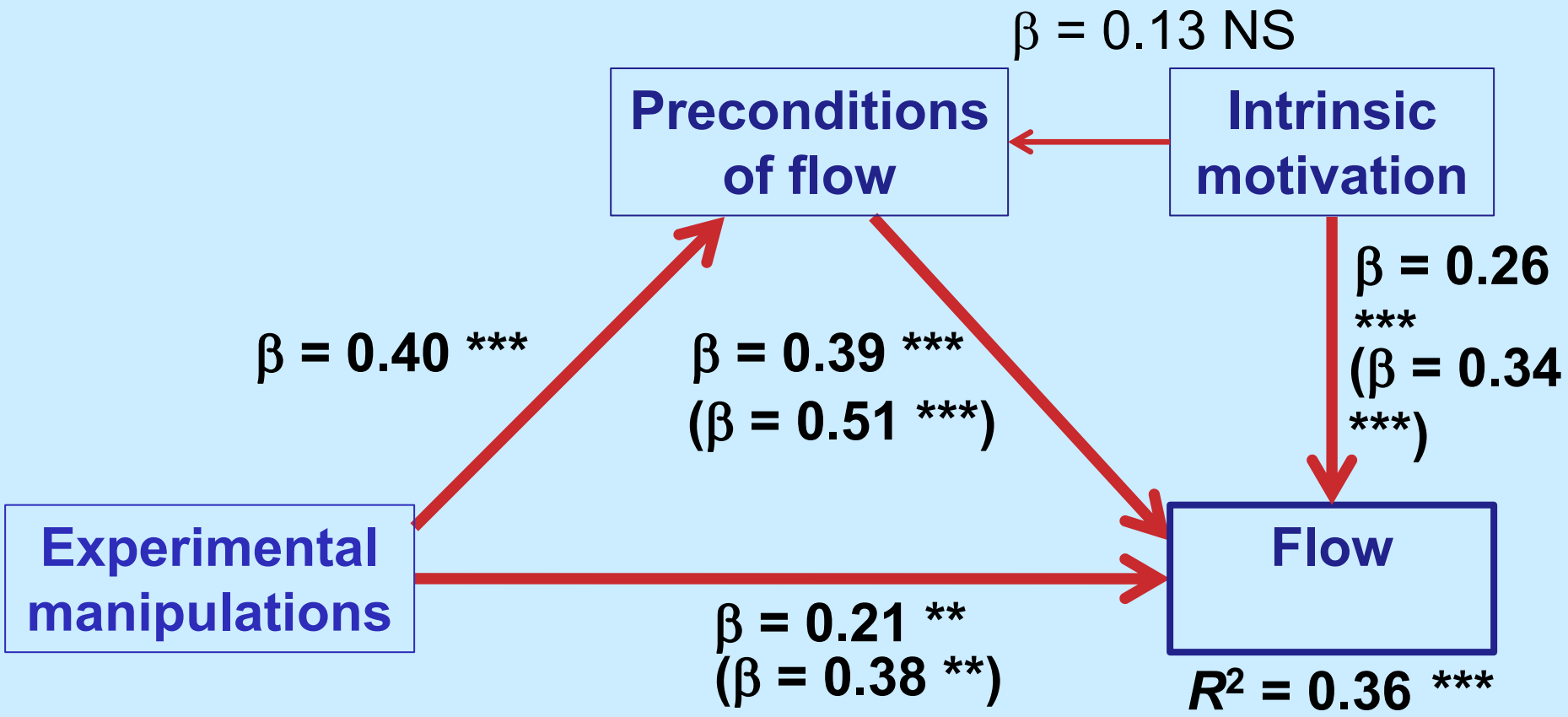

β = 0.13 NS
Preconditions of flow
Intrinsic motivation
β = 0.26 ***
(β = 0.34 ***)
β = 0.40 ***
β = 0.39 ***
(β = 0.51 ***)
Experimental manipulations
Flow
β = 0.21 **
(β = 0.38 **)
R² = 0.36 ***

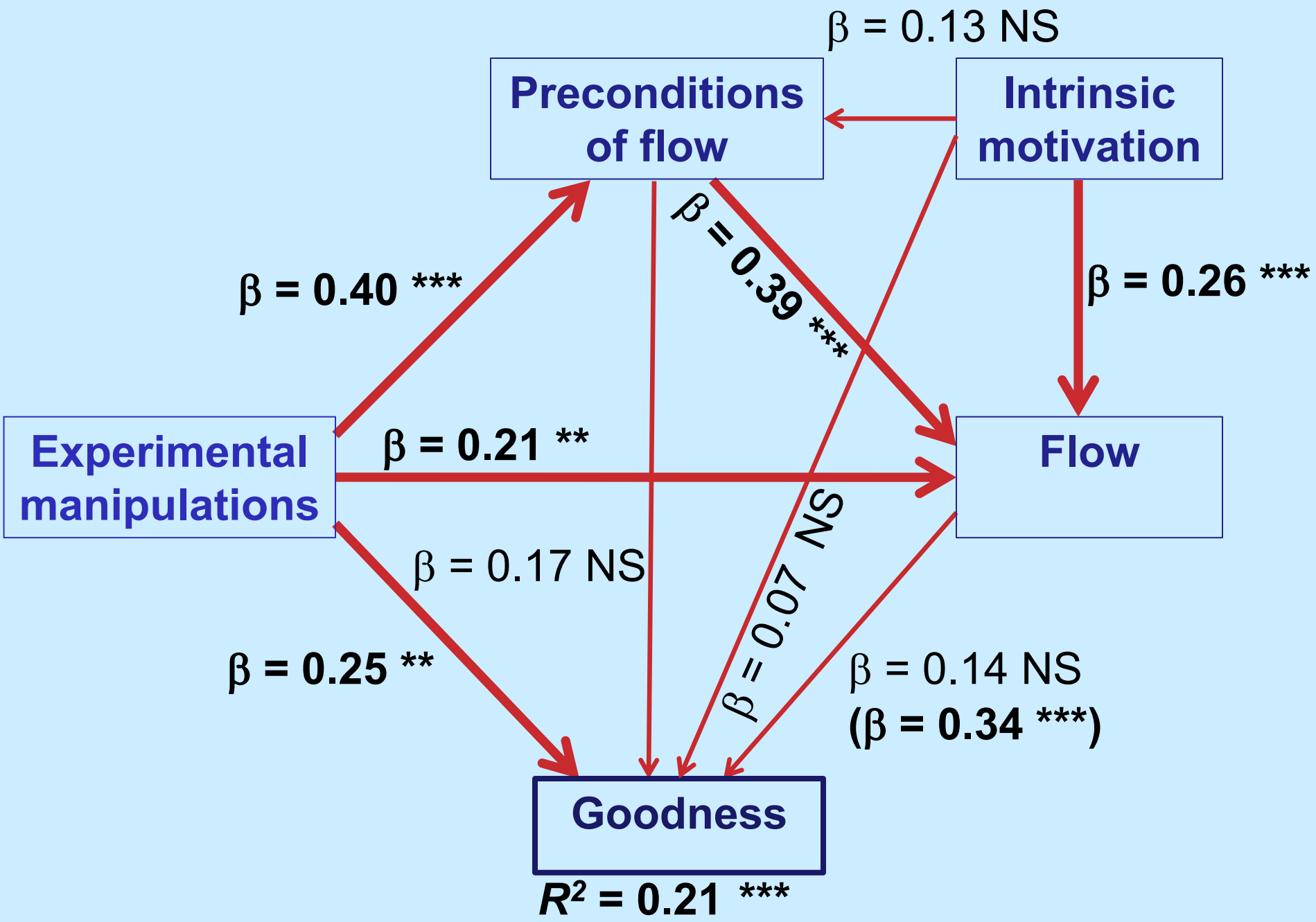

β = 0.13 NS
Preconditions of flow
Intrinsic motivation
β = 0.40 ***
β = 0.39***
β= 0.26 ***
Experimental manipulations
β = 0.21 **
Flow
β = 0.30 ***
β = 0.63 ***
β = -0.03 NS
β = -0.09 NS
(β = 0.27 **)
Task outcome
R2 = 0.57 ***

The effects of experimental manipulations, intrinsic motivation, preconditions and flow on goodness

- Experimental manipulations: combinations of the manipulations of site complexity and task complexity
- Figures in brackets: total effect of antecedents on consequents
- * p < 0.05. ** p < 0.01. *** p < 0.001.


β = 0.13 NS (β = 0.17 *)
Preconditions of flow
Intrinsic motivation
β = 0.40 ***
(β = 0.41 ***)
β = 0.11 NS
(β = 0.17 NS)
Experimental manipulations
β = 0.23 **
(β = 0.36 ***)
β = 0.27 **
(β = 0.37 ***)
Goodness
R² = 0.20 ***


β = 0.13 NS
Preconditions of flow
Intrinsic motivation
β = 0.26 ***
(β = 0.34 ***)
β = 0.40 ***
β = 0.39 ***
(β = 0.51 ***)
Experimental manipulations
Flow
β = 0.21 **
(β = 0.38 **)
R² = 0.36 ***


β = 0.13 NS
Preconditions of flow
Intrinsic motivation
β = 0.40 ***
β = 0.39 ***
β = 0.26 ***
Experimental manipulations
β = 0.21 **
Flow
β = 0.17 NS
β = 0.07 NS
β = 0.25 **
β = 0.14 NS
(β = 0.34 ***)
Goodness
R² = 0.21 ***

Evaluation of hypotheses (1)

- **Effect of task complexity**

  H1a/b/c supported – evidence for cognitive task variable as a determinant of cognitive performance/preconditions/flow proper

- **Effect of artefact complexity**

  H2a/b/c/ supported – evidence for cognitive artefact variable as a determinant of cognitive performance/preconditions/flow proper

- **Effect of intrinsic motivation**
  - H3c supported – evidence for motivational personal variable as a determinant of flow proper
  - H3b partially supported
  - H3a not supported

Evaluation of hypotheses (2)

- **Effect of experimental manipulations on task outcome mediated by preconditions**

  H5 supported – evidence for preconditions as cognitive component of flow/determinant of task outcome

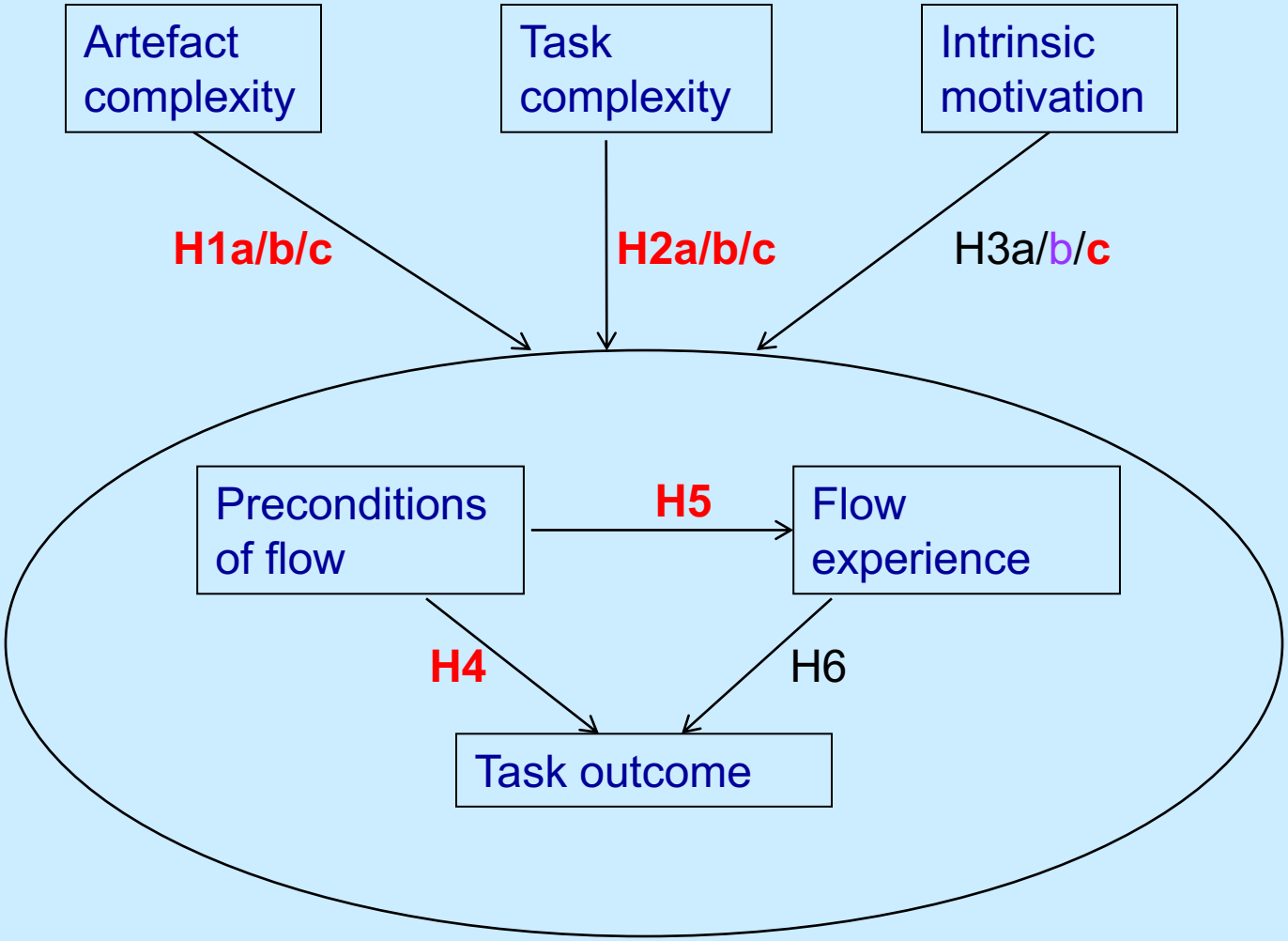
- **Effect of experimental manipulations on flow mediated by preconditions**

  H4 supported – evidence for preconditions as a determinant of flow

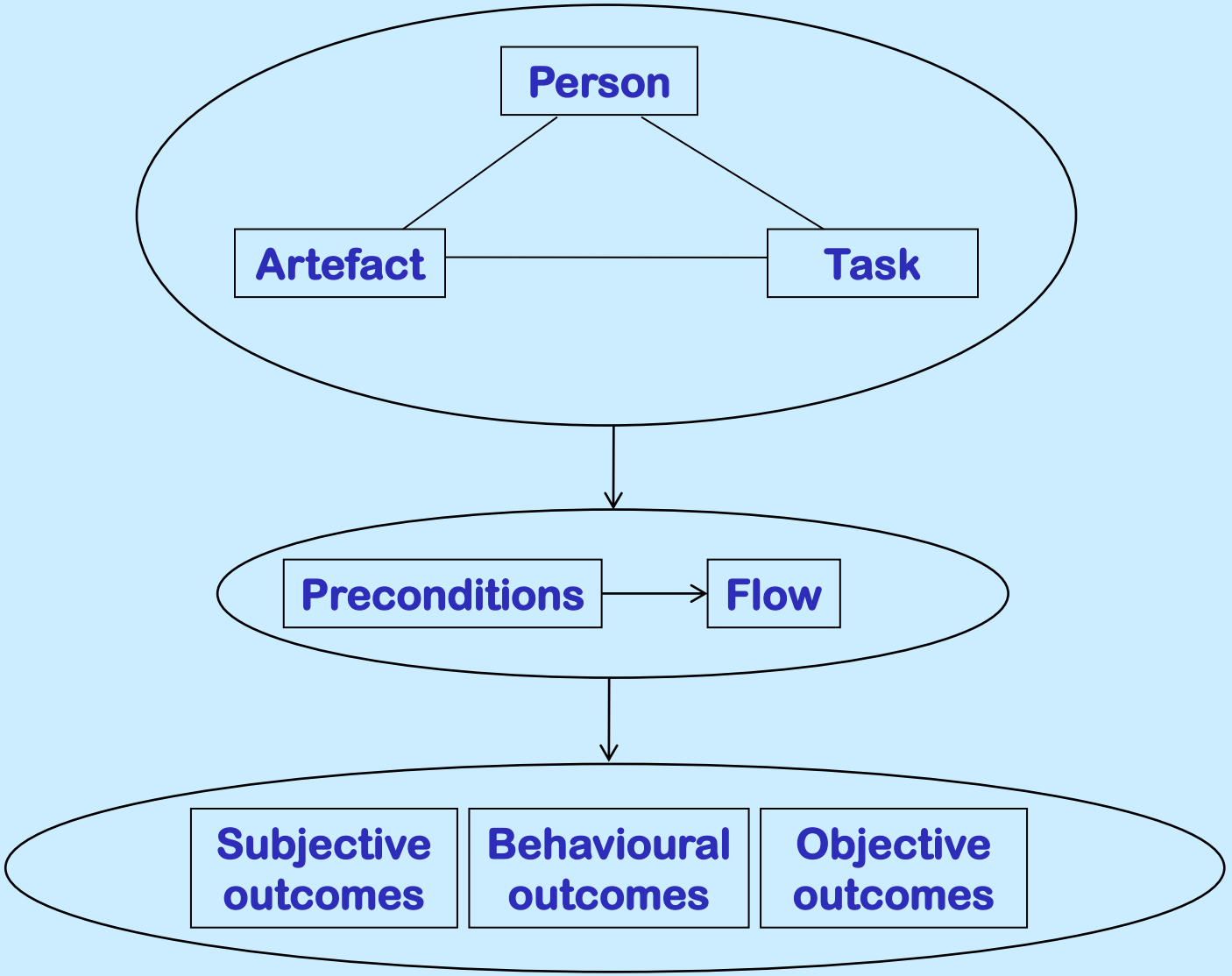
- **Effect of experimental manipulations on task outcome not mediated by flow**

  H6 not supported, but motivation expected to be a (stronger) determinant of task outcome when task importance is high (Engeser & Rheinberg, 2008)

Summary


Artefact complexity
Task complexity
Intrinsic motivation
H1a/b/c
H2a/b/c
H3a/b/c
Preconditions of flow
H5
Flow experience
H4
H6
Task outcome

Implications within research literature



Implications for HCI (1)

By applying Norman's (1998) principles of good design usable design can promote the preconditions of flow

- Good conceptual mapping → challenge/skill balance
- Visibility and good mapping → goal clarity
- Feedback → feedback

Implications for HCI (2)

Create better user-interfaces by considering PAT factors in relation to flow

- Person
  - E.g. 1: skill level
  - E.g. 2: achievement motivation as a moderator of the effect of challenge/skill balance on flow (Engeser & Rheinberg, 2008; Schüler, 2007)
- Artefact
  - E.g.: usable design → preconditions of flow
- Task

  E.g.: task importance: in important tasks (using 'missing-critical' systems) skills should (far) exceed challenge
  (a) for safety
  (b) to increase flow and, thereby, task performance

Implications for HCI (3)

- **Objective and subjective outcomes of flow**

  E.g.: perpetually flow-producing computers to enhance psychological well-being and thereby, ultimately,

  - physical health (based on Steele & Fullagar, 2009) and
  - stable psychological dispositions such as satisfaction with life (based on Asakawa, 2010)

- **Behavioural outcomes of flow**
  - By promoting flow, motivation towards repeat-behaviour at a more challenging level can be achieved, leading to further flow
  - Behaviour can be positive or negative (e.g. computer-game addiction)

Need fulfilment

- In the context of need fulfilment, flow may be "understood as a variant of a competence experience" (Hassenzahl et al., 2010, p. 361)
- The needs that flow can fulfil are not necessarily the only ones in HCI
- But, flow has important implications as a powerful tool in HCI

Conclusions

- Staged model of flow implies crucial role of preconditions of flow in HCI and beyond
- Flow is a mediator of the effect of PAT factors on objective outcomes (task outcome), but potentially also on behaviour and subjective outcomes
- Future work in HCI should exploit the potential of computers to promote flow experience and, thereby ultimately, the quality of life

More interaction experience

- Schaik, P. van, Hassenzahl, M. & Ling, J. (2012, accepted for publication). User-experience from an inference perspective. *ACM Transactions on Computer-Human Interaction*.
- Schaik, P. van & Ling, J. (2007). Design parameters of rating scales for web sites. *ACM Transactions on Computer-Human Interaction*, *14*(1), Article 4.

Final words

"Someone who knows everything that can be known has a lot of knowledge. But why would he (/she) want to know everything? Knowledge without a purpose is in fact non-knowledge." (p. 84)

Toonder, M. (1980). The know-hat [De weetmuts]. In M. Toonder. *There is something behind this* [*Daar zit iets achter*]. Amsterdam: De Bezige Bij.

Questions?

Ask me now (*Thelonious Monk, Genius of Modern Music, Volume 2*, 1952)