

# *In vivo* experimentation: An introduction

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## Outline

- ◆ *In vivo* experimentation:
  - Motivation & definition
- ◆ 3 examples
  - Reflection on the 3 examples
- ◆ Distinguishing *in vivo* from other types of experiments
- ◆ Quiz & discussion
- ◆ IV track activities for rest of the week

Next

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## What is the problem?

- ◆ Need external validity
  - Address real instructional problems & content
  - Authentic students (e.g., backgrounds, pre-training)
  - Authentic context (e.g., motivations, social interactions, etc.)
- ◆ Need internal validity
  - Control of variables to avoid confounds
    - ◆ E.g., instructor effects

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## Three approaches

- ◆ Traditional
  - Laboratory experiments
  - Classroom experiments
- ◆ Novel
  - *In vivo* experimentation

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## Lab experiments

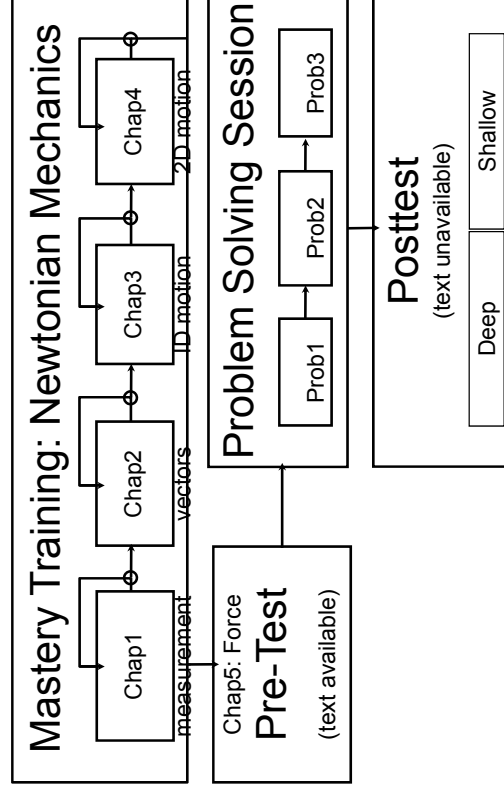
- ◆ **Students**
  - Volunteers (recruited from classes?)
  - Motivated by money (or credit in psych course)
- ◆ **Context**
  - Instruction done in a lab (empty classroom?)
  - Experimenter or software does the instruction
  - Maximum of 2 hours per session
- ◆ **Typical design**
  - Pre-test, instruction, post-test(s)
  - Conditions differ in only 1 variable/factor
- ◆ **High internal validity; low external validity**

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## Chi, Roy, & Hausmann (2008)



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## Classroom experiments

- ◆ **Participants & context**
  - Students from real classes
  - Regular instructors (not experimenter) does teaching
- ◆ **Design**
  - Train instructors to vary their instruction
  - Observe classes to check that manipulation occurred
  - Assess via embedded pre- and post-test(s), or video
- ◆ **High external validity; low internal validity**
  - Weak control of variables

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## In vivo experimentation

- ◆ **Students and context**
  - In a real classroom with real students, teachers
  - Software controls part of instruction
    - ◆ In-class and/or homework exercises
    - ◆ Records all interactions (= log data)
- ◆ **Design**
  - Manipulation
    - ◆ Software's instruction differs slightly over a long period, or
    - ◆ More dramatic difference during one or two lessons
  - Assessment via regular class tests & log data

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## 1st example: Wang, Lui & Perfetti's Chinese tone learning experiment

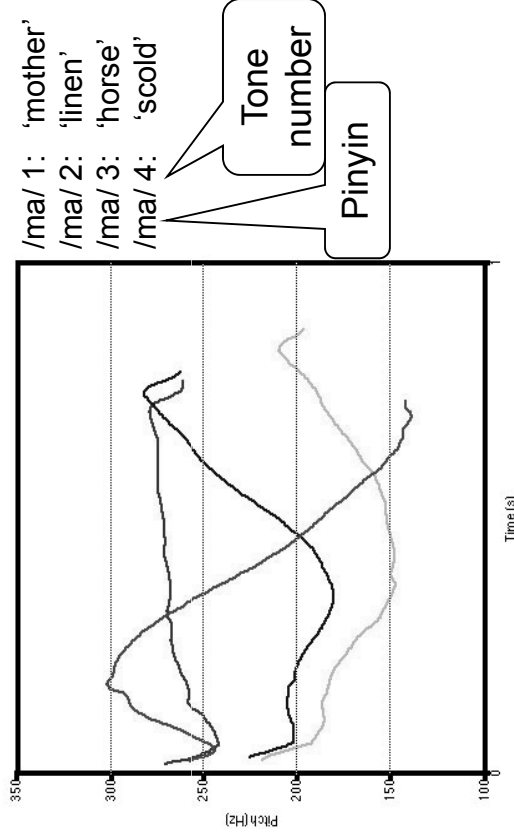
- ◆ **Context**
  - CMU Chinese course
  - On-line exercises
    - ◆ Given spoken syllable, which tone (of 4) did you hear?
  - Very difficult to learn
- ◆ **Hypothesis**
  - Earlier work → subtle wave form differences exist
  - Does displaying them help?

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## Chinese tones



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## Design

- ◆ **Conditions**
  - All conditions select tone from menu
  - All conditions given sound + ...
    - ◆ Experiment: wave form & Pinyin
    - ◆ Control 1: number & Pinyin
    - ◆ Control 2: wave form
- ◆ **Procedure**
  - Pre-test
  - One exercise session per week for 8 weeks
  - Several post-test

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## Preliminary results

- ◆ Error rates during training
  - Experiments < Controls on lessons 2, 5, 6 & 7
- ◆ Pre/Post test gains
  - Experiments > Control 1 on some measures
  - Control 2 – too few participants
- ◆ Tentative conclusion
  - Displaying waveforms increases learning
  - Second semester data being analyzed
  - Other data being analyzed

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## Hausmann & VanLehn (2007)

- ◆ The **generation hypothesis:** self-explanation > instructional explanation
  - Quick—f\_\_\_ > Quick—fast (Slameka & Graf, 1978)
  - The fat man read about the thin ice. (Bransford et al.)
  - How can a worm hide from a bird? (Brown & Kane)
- ◆ The **coverage hypothesis:** self-explanation = instructional explanation
  - Path-independence (Klahr & Nigam, 2004)
  - Multiple paths to mastery (Nokes & Ohlsson, 2005)
  - Variations on help (Anderson et al., 1995)

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## Why is this an *in vivo* experiment?

- ◆ External validity
  - Real class, student, teachers
  - Post-tests counted in students' grades
    - ◆ Cramming?
- ◆ Internal validity
  - Varied only two factors: waveform, Pinyin
  - Collected log data throughout the semester
    - ◆ Who actually did the exercises?
    - ◆ Error rates, error types, latencies
  - Student profiles

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The screenshot shows the ANDIS Physics Workbench interface. The main window displays a physics problem: "A charged particle is in a region where there is an electric field  $E$  of magnitude 24.4 V/m at an angle of 17 degrees above the positive x-axis. If the charge on the particle is 8.4 C, find the magnitude of the force on the particle  $P$  due to the electric field." A diagram shows a coordinate system with x and y axes, a point P, and a force vector  $F_e$  pointing into the first quadrant. The solution window is open, showing the answer "305N" and a list of variables:  $q = 8.4C$ ,  $E = 24.4V/m$ ,  $\theta = 17^\circ$ . Annotations include: "Variable q defined for charge" pointing to the charge variable; "Equation:  $F_e = \text{abs}(q)*E$ " pointing to the force calculation; "Immediate Feedback via color" pointing to the solution window; "Help request buttons" pointing to the help icons; "Force due to Electric Field" pointing to the force vector in the diagram; "Bottom-out hint" pointing to the hint text: "T: You can find the value of the magnitude of electric field at the region at 10 due to an unspecified agent at 10 in the problem. Explain further OK"; and "Bottom-out hint" pointing to the final instruction: "T: Enter the equation  $E1 = 24.4 V/m$ . OK".

## Terminology

- ◆ **Example** = problem + multi-entry solution
- ◆ **Complete example** = every entry is explained
  - “Because the force due to an electric field is always parallel to the field, we draw Fe at 17 degrees. It’s in this direction because the charge is positive. If it had been negative, it would be in the opposite direction, namely 197 degrees.”
- ◆ **Incomplete example** = no explanations of entries
  - “We draw Fe at 17 degrees.”

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## Study design

	Prompted to paraphrase	Prompted to self-explain
Incomplete Example (each entry presented without explanation)	No explanation → no learning	Self-explanation → learning
Complete Example (explains each entry)	Instructional explanation → ????	Self-explanation → learning

Generation hypothesis: No learning

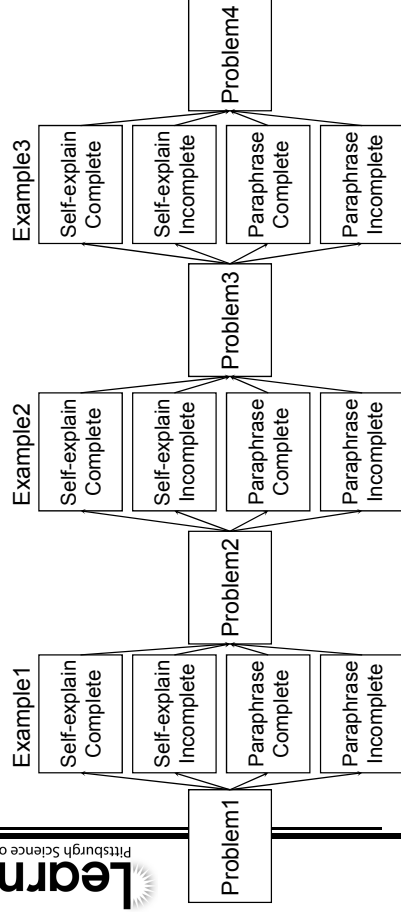
Coverage hypothesis: Learning

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## Procedure: Each problem serves as a pre-, mid- or post-test



## Dependent variables (DVs)

- ◆ Log data from problem solving
  - Before, during and after the manipulation
  - Errors
  - Help requests
  - Bottom-out hints
  - Learning curves
- ◆ Audio recordings of student’s explanations
- ◆ Midterm exam

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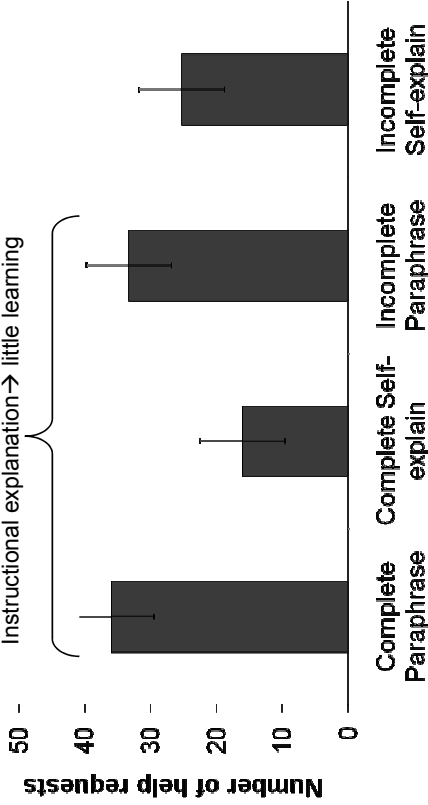
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## DV: Help requests

Supports the generation hypothesis:  
Instructional explanation → little learning



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## Butcher & Aleven (2007)

- ◆ Scientific Problem
  - Can coordination between and integration of visual and verbal information improve robust learning?
  - Can this integration be supported by scaffolds during tutored practice?
- ◆ Hypothesis
  - Interacting and self-explaining with geometry diagrams will:
    - ◆ Decrease use shallow problem-solving strategies
    - ◆ Support integration of verbal and visual knowledge

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## Study design

Site of Interaction During Problem Solving

Type of Explanation	DIAGRAM (Contiguous) GEOMETRY RULE (Verbal Explanation)	DIAGRAM (Contiguous) GEOMETRY RULE (Verbal Explanation)
TABLE (Non-contiguous) GEOMETRY RULE (Verbal Explanation)	DIAGRAM (Contiguous) GEOMETRY RULE (Verbal Explanation)	DIAGRAM (Contiguous) GEOMETRY RULE + APPLICATION (Verbal + Visual Expl.)
TABLE (Non-contiguous) GEOMETRY RULE + APPLICATION (Verbal + Visual Expl.)	DIAGRAM (Contiguous) GEOMETRY RULE + APPLICATION (Verbal + Visual Expl.)	DIAGRAM (Contiguous) GEOMETRY RULE + APPLICATION (Verbal + Visual Expl.)

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## Variable 1: Site of Interaction (Table v. Diagram)

**DIAGRAM**  
A team of archaeologists on the Texas-Louisiana border excavated several broken arrowheads. Without the arrowheads' original owners, they were unable to determine the tribal ancestry of the arrowheads. To determine the tribal ancestry of the arrowheads, the archaeologists need to know how sharp a point they were made from those to hunt, and therefore had arrowheads with wider points. The Cheyenne, on the other hand, made arrowheads with sharper points. The arrowheads were called at the top of the page. The archaeologists were asked to determine the measure of angle AWO. The top of the arrowheads is labeled as follows.

**READTWOOL**

Value	Rule
m∠AWO	77
m∠OAW	
m∠AWO	

**DICTION**  
Determine the measure of the angle of one of the arrows, angle AWO, equals 77 degrees. How sharp a point does the arrowhead (point AWO) have?

Hide buttons to see problem

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# Variable 1: Site of Interaction (Table v. Diagram)

**Value**      **Rule**

mcARO	77	Given
mcOWA	77	Inscribed Triangle
mcVAP	103	

**Rule =** Triangle Sum

1. D. Sutton approximates that the corner of one of the arrows, angle ARO, equals 77 degrees. How sharp a point does the arrowhead (mcVAP) have?

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# Variable 2: Type of Explanation (Rule vs. Rule + Application)

**Value**      **Rule**

mcARO	77	Given
mcOWA	77	Inscribed Triangle
mcVAP	25	

**Rule =** Triangle Sum

1. D. Sutton approximates that the corner of one of the arrows, angle ARO, equals 77 degrees. How sharp a point does the arrowhead (mcVAP) have?

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# Variable 2: Type of Explanation (Rule vs. Rule + Application)

**Value**      **Rule**

mcARO	77	Given
mcOWA	77	Inscribed Triangle
mcVAP	25	

**Rule =** Triangle Sum

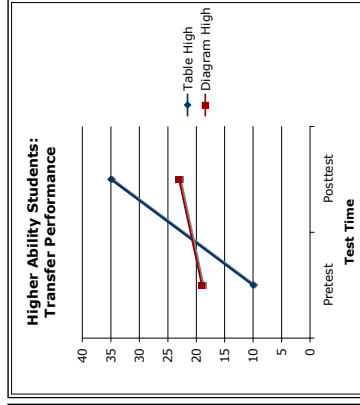
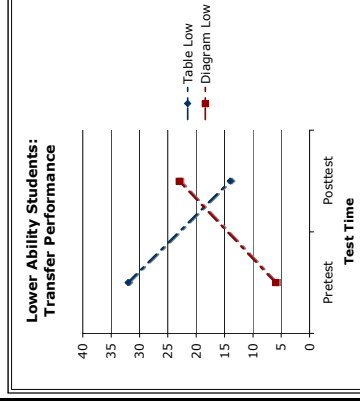
1. D. Sutton approximates that the corner of one of the arrows, angle ARO, equals 77 degrees. How sharp a point does the arrowhead (mcVAP) have?

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# Results



3-way interaction: Test Time \* Condition \* Ability:  
 $F(1, 38) = 4.3, p < .05$

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## Reflection

- ◆ Domain
  - Chinese
  - Physics
  - Geometry
- ◆ Context
  - Homework
  - Lab work
- ◆ Duration
  - Hours
  - Days
  - Weeks

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## How does *in vivo* experimentation differ from course development?

- ◆ Research problem to be solved
  - Primary: “An open question in the literature on learning is ...”
  - Secondary: “One of the hardest things for students to learn in <class> is ...”
- ◆ Scaling up not necessary
  - One unit of curriculum may suffice
- ◆ Sustainability not necessary
  - OK to use experimenter instead of technology

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## How does *in vivo* experimentation differ from lab experimentation?

- ◆ Instructional objectives and content
  - Already taught in course, or
  - Negotiated with instructor
- ◆ Control group must receive good instruction
- ◆ Logistics
  - Timing – only one opportunity per semester/year
  - Place
- ◆ Participation not guaranteed
  - Count toward the student's grade?

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## How does *in vivo* experimentation differ from classroom experimentation?

- ◆ Superficial differences
  - Treatment implemented by training teachers
    - ◆ And observing whether they teach as trained
    - ◆ Or better!
  - Can only do between-section, not between-student
  - Control groups are often absent or weak
- ◆ Underlying difference
  - Granularity of the hypotheses and manipulations
  - See next few slides

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## An example of a large-grained classroom experiment: PUMP/PAT

- ◆ Early version of CL Algebra (Koedinger et al.)
  - Tutoring system (PAT)
  - Curriculum (PUMP) including some teacher training
  - Whole year
- ◆ Hypothesis
  - PUMP/PAT is more effective than conventional instruction

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## A 2<sup>nd</sup> example of large grained classroom experiments: CECILE

- ◆ CECILE (Scardamalia, Bereiter et al.)
  - Networked collaborative learning software
  - Long, complex math activities done in small groups
  - Developed and published on the web
  - Whole year
- ◆ Hypothesis
  - CECILE community of learning increases gains

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## A 3<sup>rd</sup> example of large grained classroom experiments: *Jasper*

- ◆ Anchored instruction (Bransford et al.)
  - “Jasper” video provide a vivid, shared anchor
  - Long, complex math activities tied to anchor
  - Whole year
- ◆ Hypothesis:
  - Anchored instruction prevents inert knowledge

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## How would you classify this classroom experiment?

- ◆ Reciprocal teaching (Palinscar & Brown)
  - Small, teacher-led groups
  - Students trained two switch roles with teacher & each other
  - Multiple weeks
- ◆ Hypothesis: Reciprocal teaching is more effective than normal small group learning

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## How would you classify this classroom experiment?

- ◆ Andes tutoring system (VanLehn et al.)
  - Homework exercises done on Andes vs. paper
  - Same exercises, textbook, labs, exams, rubrics
  - Whole semester
- ◆ Hypothesis:
  - Doing homework problems on Andes is more effective than doing them on paper

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## How would you classify this experiment? (Lui, Perfetti, Mitchell et al.)

- ◆ Normal drill (used as pretraining)
  - Present Chinese character (visual) and pronunciation (sound)
  - Select English translation. Get applauded or corrected
- ◆ Manipulation
  - Select English translation. No feedback.
  - Present character, pronunciation, both or neither
- ◆ Co-training hypothesis
  - Drill with both character and pronunciation
  - > drill with either character or pronunciation (not both)
  - > no extra drill at all
- ◆ Pull out

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## Critique of *in vivo* experimentation

1. Normal instruction for several weeks
  - Including use of Andes for homework
2. Hausmann's study during a 2-hour physics lab period
3. Normal instruction for several more weeks
4. Craig's study, also during a 2-hour lab period
5. Normal instruction for several more weeks

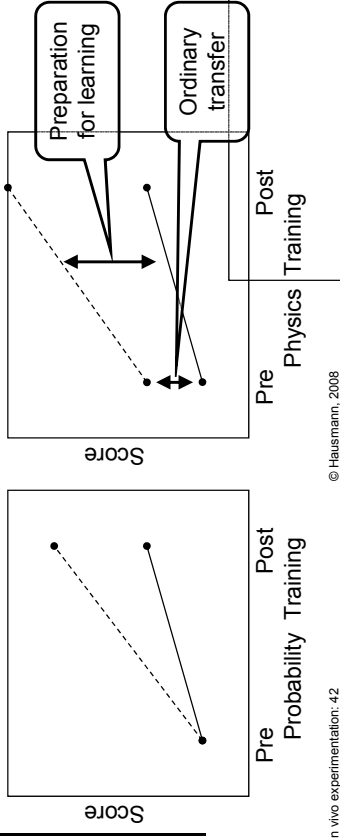
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## Should this experiment be redone *in vivo*? (Min Chi & VanLehn)

- ◆ Design
  - Training on probability then physics
  - During probability only,
    - ◆ Half students taught an explicit strategy
    - ◆ Half not taught a strategy (normal instruction)



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## Your job: Simultaneously design 3 elements of an *in vivo* experiment

- ◆ A hypothesis
  - Fits into literature on learning
  - High information value (in Shannon's sense)
- ◆ A context
  - unit of the curriculum & instructional objective
  - training content and assessments
- ◆ A manipulation
  - Tests the hypothesis
  - Fits well in the context

## Schedule

- ◆ Tuesday
  - AM: Become familiar with course & tutoring system
  - Early PM: Become familiar with theory
  - Late PM: Start writing Letter of Intent (2 pgs)
    - ◆ State background lit, hypothesis, context, manipulation
- ◆ Wednesday AM
  - Letter of Intent (LOI) due 10:45 am
  - Feedback from course committee representatives
- ◆ Wednesday PM & Thursday
  - Revise design, add details, write proposal & slides
- ◆ Friday
  - Presentation

## Contact Information

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