PS118
Applied Psychology

Human-Machine Interaction 1
Basic Concepts and Principles

Maxwell J Roberts
Department of Psychology
University of Essex
www.tubemapcentral.com

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Notes About Reading (HMI-1)

- **Textbook: Human–Machine Interaction**
  - Davey, G.C. (Ed.). (2011). *Applied psychology.* John Wiley & Sons:
    - Ch 23, Section 23.6: 23.6.1/2/3, pp. 476–479
      Ch 24, Section 24.4: 24.4.1/2/3, pp. 491–493

- **If you might be interested in a related career**
  - Designing for usability
    - Norman, D.A. (2013). *Design of everyday things*. MIT Press.
  - Information design
    - Black, A., Luna, P., Lund, O., & Walker, S. (Eds.). (2017). *Information design: research and practice*. Taylor & Francis.

Notes About Reading (HMI-2)

- **My research into *Information Design***
  - Transit maps as complex information design
    - Roberts, M.J. (2014). Schematic maps in the laboratory. Schematic Mapping Workshop 2014, University of Essex, April.
    - Roberts, M.J. (2014). What's your theory of effective schematic map design? Schematic Mapping Workshop 2014, University of Essex, April.
    - Roberts, M.J. (2017). From reasoning and intelligence research to information design. In N.D. Galbraith, E. Lucas & D. Over (eds.), The thinking mind: A festschrift for Ken Manktelow (pp. 178-190). Hove, UK: Psychology Press.
    - Roberts, M.J. (2019). Us versus them: Ensuring practical and psychological utility of measurements of schematic map usability. Schematic Mapping Workshop 2019, TU Wien, April.
    - Wu, H.-Y., Niedermann, B., Takahashi, S., Roberts, M.J., & Nöllenburg, M. (2020). A Survey on Transit Map Layout — from Design, Machine, and Human Perspectives. Computer Graphics Forum (Proceedings of EuroVis 2020), Vol. 39, No. 3.

Plan for the Two Lectures

- How can applied psychologists help?
  Back to basics

- Why *Human–Machine Interaction*?
  What is its context and beyond?

- Basics of Human–Machine Interaction?
  What does the textbook say?

- Transit maps as illustrations of key issues
  - Applying psychology to information design
  - Usability testing and methodological issues

How Can Applied Psychology Help?

- What is applied psychology?

  - IDEALLY

    The application of theories and findings from scientific psychology in order to answer real-world questions

  - BUT INSTEAD

    The creation of theories and findings within a real-world domain that psychologists have been able to land-grab

How Can Applied Psychology Help?

- How can psychology be applied?

  "I would like to make X better, can you help me?"

  "I have a problem with X, can you help me?"

  - Three strategies …

How Can Applied Psychology Help?

- How can psychology be applied?

1. Look at basic theories and findings, what does the textbook prescribe?

   Problems:

   - Scientific psychology is reductionistic, difficult to scale up from simplistic theories to real-world complexity
   - Hard to pin these down to specific prescriptions.
   - Practitioners often don't like vague generalisations and contingent advice, may go somewhere else

How Can Applied Psychology Help?

- How can psychology be applied?

2. Use basic theories and findings to critique practice, what does the textbook suggest?

Problems:

- Easy to be wise after the event
- Frighteningly easy to do this, psychology theories are adaptable enough to have infinite explanatory power
- Can lead to an emphasis on negative advice (*don't do this, don't do that*)
- Positive predictions and advice much harder to attain

How Can Applied Psychology Help?

- How can psychology be applied?

3. Use tools/methodologies that psychologists happen to have learnt in order to answer specific questions

Problems:

- What textbook? Psychologists versus technicians?
- Risks losing the unique selling points of being a psychologist
- Real life is complex, difficult to reduce questions to simple barest essentials that can be investigated empirically
- Results can be hard to generalise and integrate to create wide-ranging theories

How Can Applied Psychology Help?

- How does this affect me?

  - Think about the approaches taken by applied psychologists in general, their strengths/weaknesses
  - Be careful when simple psychology theories suggest easy remedies, *interventions can make things worse*
  - Psychology no longer a ‘young science’, for long term success scientific psychology *should* provide answers

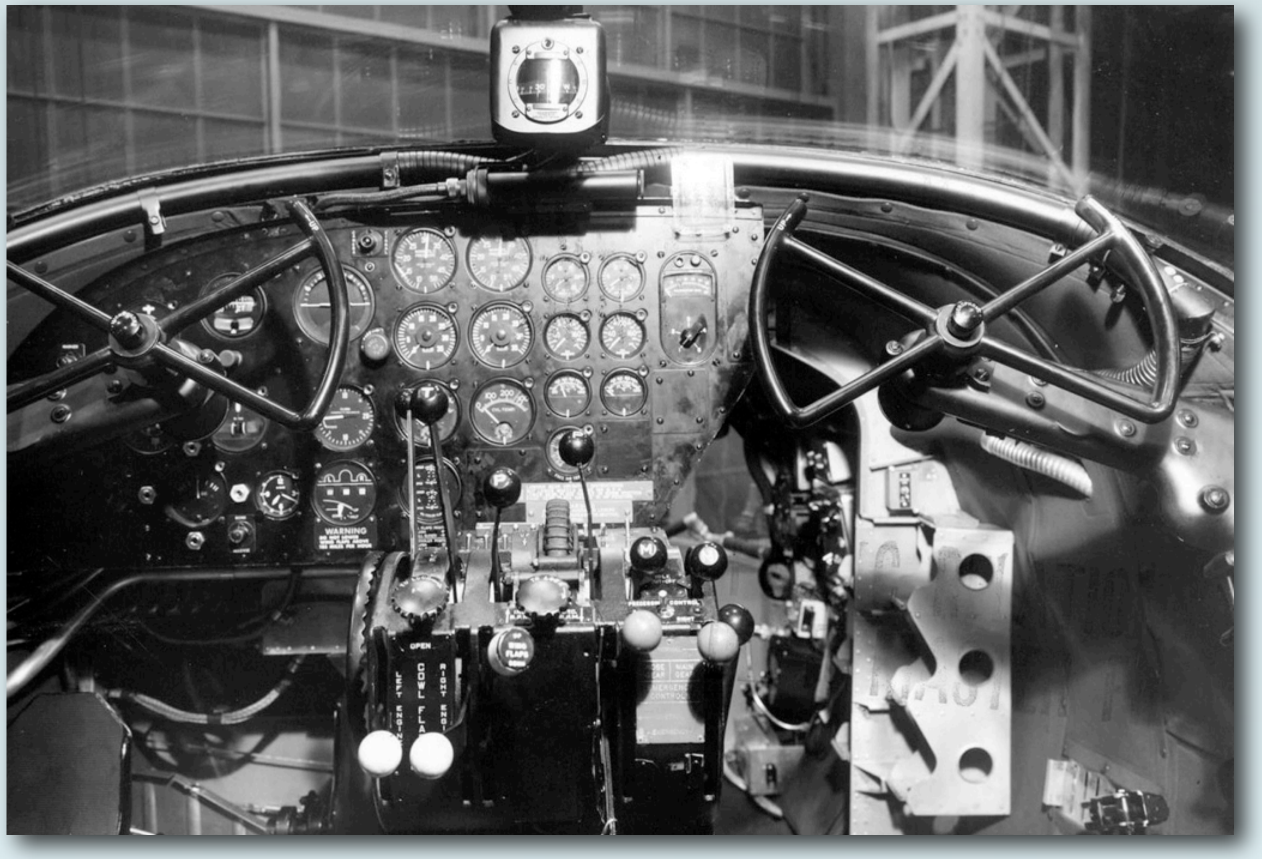
Why Human–Machine Interaction?

- Occupational Psychology
  - Applying psychology in order to improve the productivity (and happiness) of the workforce

- Machines are a recurring problem
  - Equipment can be complicated, dangerous, expensive
  - People are cheap, but inefficient and make mistakes
  - Interest taken in *human-machine interaction* since the early 20th Century

Why Human–Machine Interaction?

- Aviation (origins from First World War)



- Initial emphasis: identifying people best able to cope and then training them
- As complexity increased, a shift towards designing controls matched to human strengths and limitations

Why Human–Machine Interaction?

- Time and Motion Studies (origins from early 20th C.)

  - Identify component parts of a task
  - Reorganise and reconfigure these so as to maximise efficiency
  - Emphasis on fitting humans to production process

Why Human–Machine Interaction?

- Human Factors, or Ergonomics (origins from 1950s)

  Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design to optimize human well-being and overall system performance

  - *Physical ergonomics:*
    human anatomy and the work environment
  - *Cognitive ergonomics:*
    mental processes and the work environment
  - *Organisational ergonomics:*
    social processes and the work environment

Why Human–Machine Interaction?

- Advances in technology reduce the prevalence of clerical and manual work
- Computers become widespread in the workplace

- Early computers difficult to use, mistakes expensive
- Today, human–***machine*** interaction usually means human-***computer*** interaction

Why Human–Machine Interaction?

- From 1980s, high computer power becomes affordable

  - No longer confined to workplace
  - Must be usable by people who do not necessarily have access to training
  - Computer usability is no longer an occupational issue

Beyond Human–Machine Interaction

- Computers partly machine, partly *information*
    - How do people make sense of information?
    - How does the presentation of information affect its interpretation?
    - Why do people make mistakes?

- Gottfredson (2004): ***Functional literacy***
    - *“using printed and written information to function in society, to achieve one’s goals and to develop one’s knowledge and potential”*
    - *“48% of American adults […] do not have skills adequate for competing in a global economy and exercising fully their rights and responsibilities of citizenship“*

Beyond Human–Machine Interaction

- Computer usability related to the disciplines of ***Information Design*** and *Data Visualisation*

  The practice of presenting information in a way that facilitates its efficient and effective understanding

- Black *et al.* (2017) topics include:
  - Medical information
  - Wayfinding/wayshowing
  - Exhibition design
  - Official information leaflets
  - Pictograms and symbols
  - Type and typography

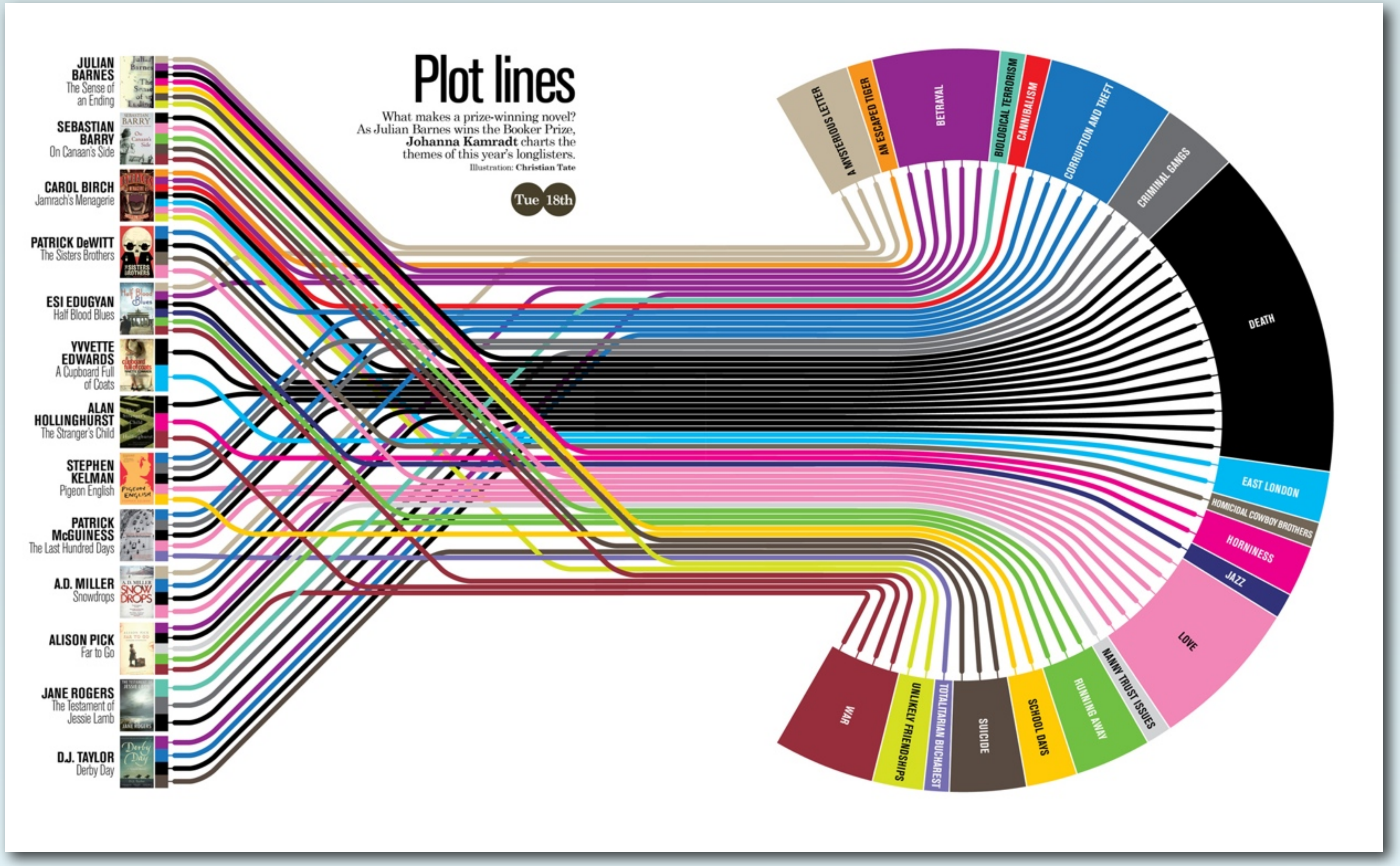
Beyond Human–Machine Interaction

- Computer usability related to the disciplines of *Information Design* and ***Data Visualisation***

  The graphical visualisation of complex data to make salient any underlying patterns such as correlation and causality

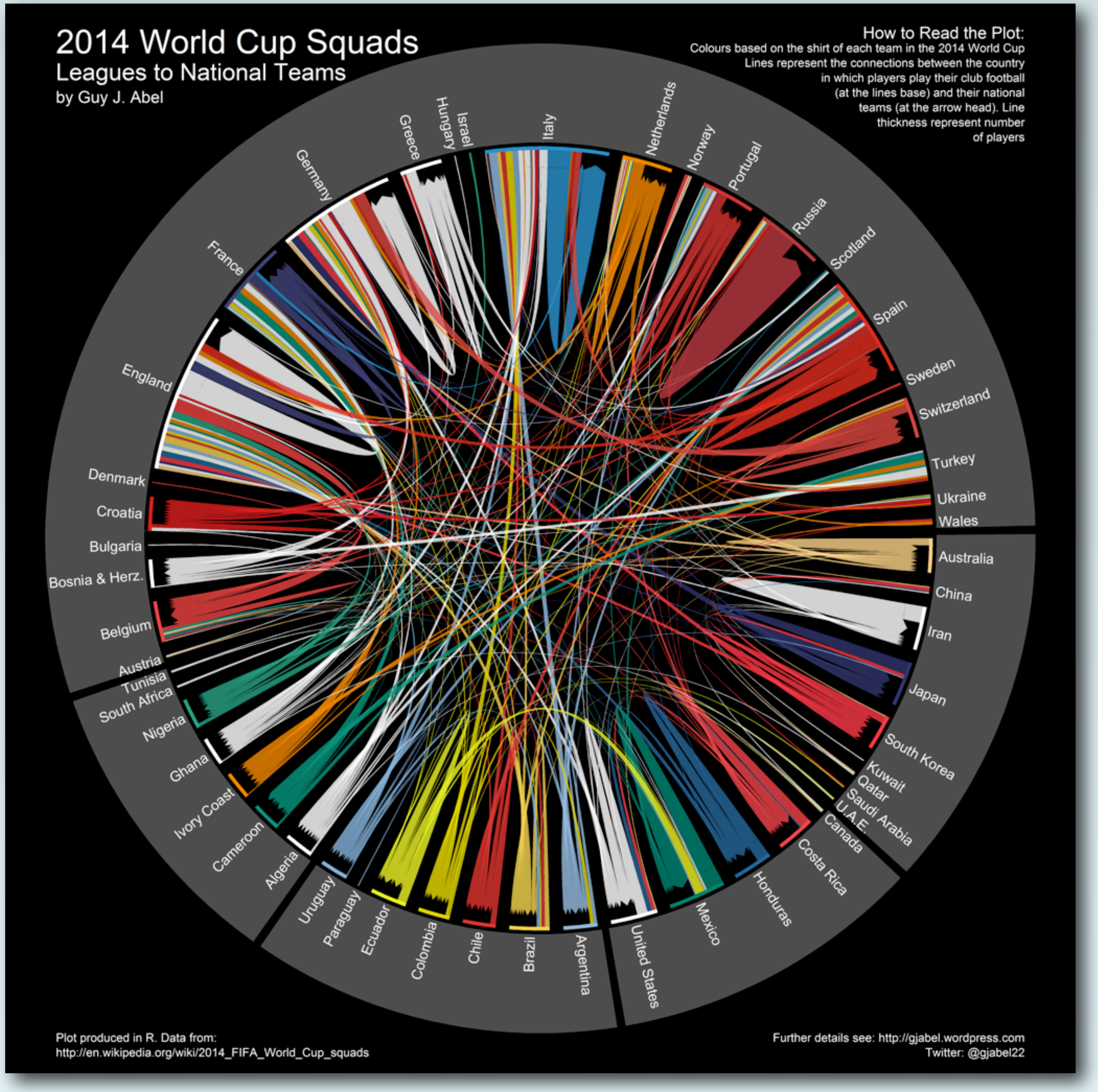
Beyond Human–Machine Interaction

- Computer usability related to the disciplines of *Information Design* and ***Data Visualisation***



Beyond Human–Machine Interaction

- Computer usability related to the disciplines of *Information Design* and ***Data Visualisation***



Beyond Human–Machine Interaction

- Computer usability related to the disciplines of *Information Design* and ***Data Visualisation***

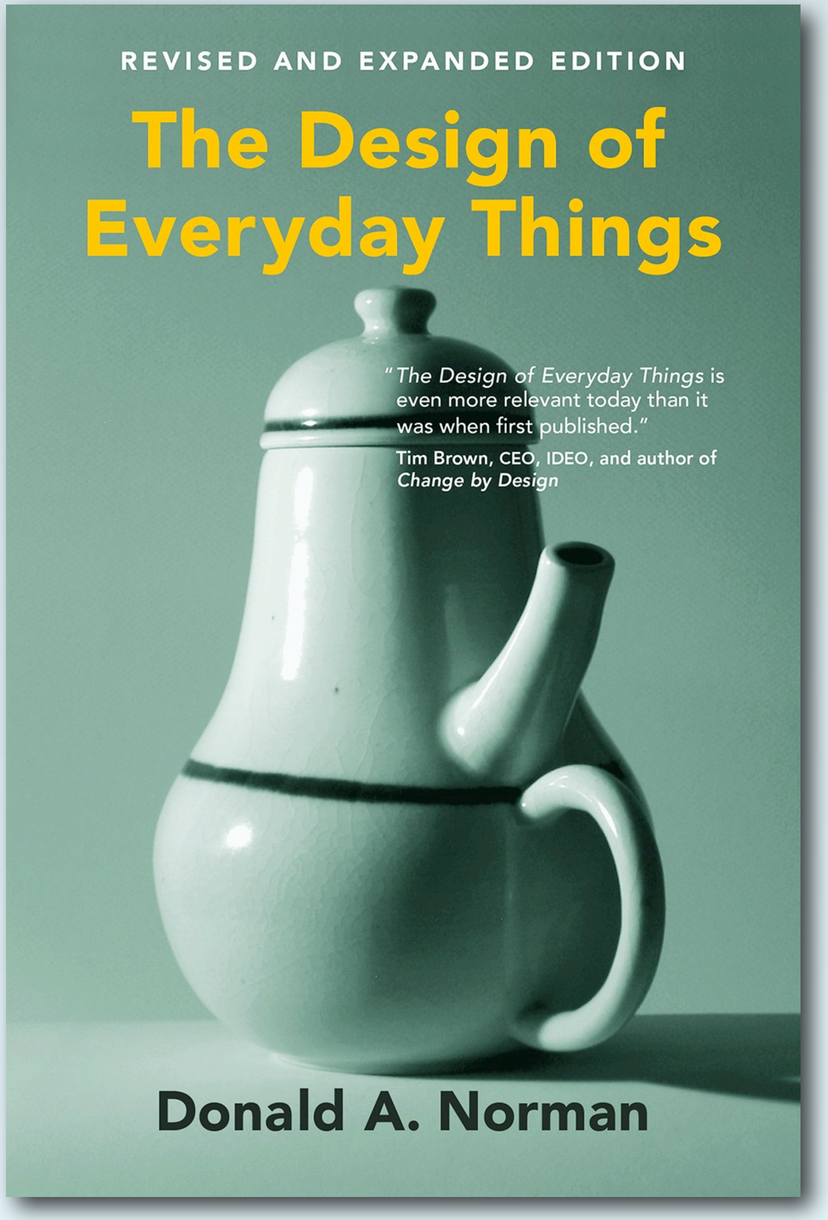
- Many popular books and web sites
  - Practitioners are often computer scientists and graphic designers
  - Technology-driven and designed for aesthetic impact rather than psychology-driven
  - Complex data leads to graphics that can be difficult to interpret and verify
  - Usability – ease of interpretation – is a psychological issue

Beyond Human–Machine Interaction

- We have to make sense of a complicated information-dense world, our prosperity/well-being depends this
    - Computers no longer special (1), *information presenters,* e.g., apps, web pages
    - Computers no longer special (2), *everyday devices,* e.g., cars, televisions, washing machines
    - Simple everyday things can lead to errors, ***everything*** should be designed effectively

Beyond Human–Machine Interaction

- Norman (2013): when everyday devices lead to mistakes, the fault lies with the designer, not the user
- *Human centred design:* take account of a person's needs, expectations and abilities
    - *Discoverability:* how easily can the user work out the functions of a device?
    - *Understanding:* how easily can the user work out how to operate a device?
    - Important concepts include *affordances, signifiers, feedback* and *mental models*



Basics of Human–Machine Interaction

- Goal = optimise interactions between humans and machines (at the workplace)
  - Design machines to fit humans, ***not*** train humans to fit machines
  - Allocate duties effectively between the two
    - Humans (*inductive*):
      + creativity, identifying patterns & meanings, error-tolerance, common sense judgement
      – precision memory, extended vigilance, rapid calculation
    - Computers (*deductive*):
      + precision memory, calculation, monitoring
      – common-sense judgement
  - Bad allocation: human has to work harder to compensate for machine failings

Basics of Human–Machine Interaction

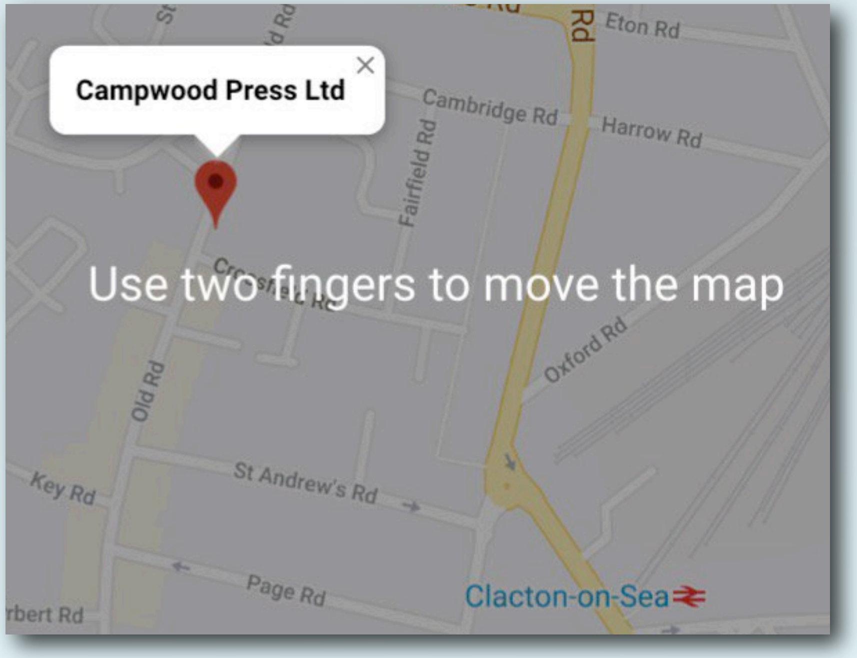
- Matching basic systems to human cognition
  - *Displays* should …
    - Format information in a way compatible with its use
    - For example, absolute measurement versus rate of change, such as aircraft altimeters

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - *Displays* should …
    - Show ***exactly*** the information relevant to the task
      - Human limited working memory capacity = *Information out of view can be easily forgotten or neglected*
      - Human limited attentional resources = *Too much information, or irrelevant information can overwhelm cognitive resources, may lead to vital information being neglected*
    - For complex tasks, this requires an intelligent display that can anticipate what is needed in every eventuality

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - *Controls* should …
    - Be intuitive and congruent
      - For example, ***up*** versus ***down***
      - Acquiesce to natural human behaviour



- Provide positive and clear feedback of their operation, very important for touch-screens

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - Errors range from deleting a file to crashing a train to destroying a nuclear power station
  - Human error can be reduced but not eliminated
    - Cognitive remedies
      e.g., design to minimise cognitive pressure-points
      fail-safes to stop error propagation
    - *Cultural remedies*
      e.g., procedures, awareness, vigilance

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - Serious incidents are often multi-factorial,
    - Organisational complacency and inadequate safety systems provide a potentially dangerous environment
    - Minor incidents are contained, complacency reinforced, safety issues not addressed, disincentive to report issues
    - Single human error followed by disaster provides obvious/ wrong scapegoat for catastrophic confluence of events

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - Swiss Cheese Model of catastrophic incidents (Reason *et al.*, 2006).

    A system has multiple layers of defences, but if the breaches (bubbles/holes) line up then disaster results

    - Single *active error* is the apparent cause of an incident
    - But *systemic weaknesses* provide the environment which enables the *active error* to lead to a major incident

  - Eliminating errors of individuals can only go so far, systemic weaknesses should be identified/addressed

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - Ladbroke Grove Rail Disaster, 1999
    - See Lawton & Ward (2005), Stanton & Walker (2011)
    - High speed head-on rail collision
      just outside Paddington station
    - 31 people killed, including both drivers
      417 people injured

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - Ladbroke Grove Rail Disaster, 1999
    - *Active Error:* Inexperienced driver passed red signal

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
    - Ladbroke Grove Rail Disaster, 1999
        - *Systemic Weaknesses:*
            - Signal concerned was poorly sited, difficult to see in morning sun, drivers had complained about it
            - Signal had been passed at red before, but attributed to human error, not safety weakness, no remedial action
            - Inadequate training, rogue signal not highlighted as element that drivers should be careful with

Basics of Human–Machine Interaction

- Matching basic systems to human cognition
  - Ladbroke Grove Rail Disaster, 1999
    - *Systemic Weaknesses:*
      - Auditory warning for red aspect is ***identical*** to yellow, but these aspects have different meanings and rules
        - Yellow: ***caution***, slow down,
          it is permitted to pass this signal
        - Red: ***danger****, stop,*
          it is forbidden to pass this signal
      - No train auto-stop for passing a signal showing red
    - Driver action *just one* component of the causal network
    - *Systemic weaknesses* provided the latent environment in which a disaster took place after a human error

Basics of Human–Machine Interaction

- Types and origins of human errors
  - The effects of errors can range from irritating to catastrophic
  - Cultural and cognitive remedies can help accommodate the tendencies for human error
  - Understanding of the *cause* of errors can assist this
    - Situations prone to causing errors – *cognitive pressure-points* – can be minimised
    - Likely errors can be anticipated and trapped e.g., using *fail-safes*

Basics of Human–Machine Interaction

- Types of human error (Reason, 1990)
  - *Unintended actions.*
    Agent's own behaviour surprises the agent
    - *Slips.* Correct plan is intended, but wrong action is taken
      e.g., want to check email, but open messaging app instead
    - *Lapses.* Correct plan is intended, but key action is omitted
      e.g., make online purchase, T&Cs agreement box not ticked

Basics of Human–Machine Interaction

- Types of human error (Reason, 1990)
  - *Intended actions.* Agent's behaviour does not surprise agent (but the outcome might)
    - *Mistakes.* Incorrect plan is intended; one or more actions will unknowingly cause goal to be failed
      e.g., upgraded software has changed functionality
    - *Violations.* Incorrect plan is intended; one or more actions will knowingly cause (imposed) goal to be failed
      e.g., failing to password-protect an internal document to be sent by email

Basics of Human–Machine Interaction

- Implications of taxonomy of human error
  - Slips, lapses, mistakes have direct cognitive causes, but the reasons for the existence of causes may be social/organisational
    - Implement cognitive remedies by attempting to understand mental processes underlying the errors
    - Investigate by social factors (e.g. resistance to cognitive remedies) in case cultural remedies are also needed
  - Violations have direct social/organisations causes
    - Make cultural remedies by attempting to understand social processes underlying these
    - But these might exist because organisational procedures are cognitively unsatisfactory

Basics of Human–Machine Interaction

- Automatic versus controlled processes (Shiffrin & Schneider, 1977)
  - *Controlled processes* make high demands on *attentional resources* and *cognitive capacity*
    - Once action is chosen, cognitive intervention is necessary for initiating and performing each step of the sequence
    - E.g., Sending multiple copies of a complicated, paginated, stapled document to a printer

Basics of Human–Machine Interaction

- Automatic versus controlled processes (Shiffrin & Schneider, 1977)
  - *Automatic processes* make low demands on *attentional resources* and *cognitive capacity*
    - Skill acquisition: repeated sequences *compiled*, so that successive steps are performed automatically
    - Once action is initiated, little or no cognitive intervention is usually required or applied

Basics of Human–Machine Interaction

- Automatic versus controlled processes (Shiffrin & Schneider, 1977)
  - *Automatic processes* make low demands on *attentional resources* and *cognitive capacity*
    - e.g., deleting files from a computer:

      1) Select empty trash from menu
      2) Press the confirm button without thinking

    - The warning is usually irrelevant, and so clicking to confirm, without thinking, becomes automated

Basics of Human–Machine Interaction

- Cognitive causes of *slips* (unintended wrong actions) and *lapses* (unintended missing actions)
    - Example of cause of a slip: insufficient attention is applied and a ***controlled procedure*** is superseded by an ***automated procedure*** that is inappropriate
    - Example of cause of lapse: memory failure to apply a particular operation in a ***controlled procedure***
- Understanding whether defective processes are controlled or automatic important for remediation

Basics of Human–Machine Interaction

- Cognitive causes of *slips* and *lapses*
  - Multiple tasks/sources of information cause vulnerabilities to slips/lapses
    - Simple distractions
    - Divided attention between tasks can result in insufficient available to intervene and prevent automated procedures
    - Same-modality competing information causes interference e.g., verbal (vs. keyboard) input and holding a conversation
    - Information might be overwritten on screen, meaning that accurate memory is required to continue to use it e.g., scrolling displays
    - Key decisions necessary in a sequence not made salient, must be actively identified and applied e.g., all the possible choices for printing a document

Basics of Human–Machine Interaction

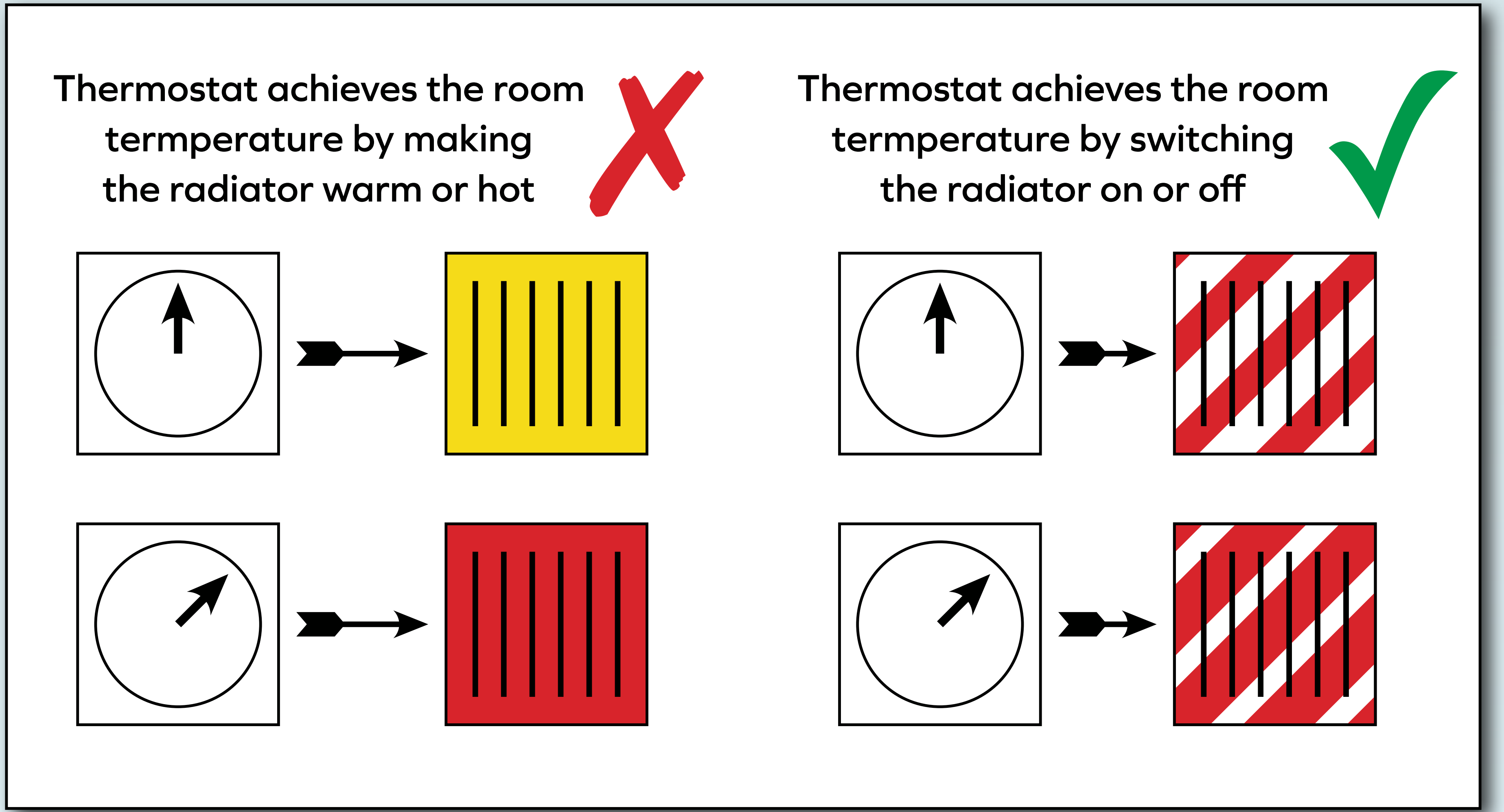
- Cognitive causes of *mistakes* (intended incorrect actions)
  1) A procedure (automated or controlled) that worked successfully in the past is now obsolete, but still applied
  2) An incorrect ***controlled procedure*** is assembled because key aspects of attaining a goal are not known, forgotten, or misunderstood
     - Stressful situations
     - Inadequate training/procedures
     - Defective *mental model*

Basics of Human–Machine Interaction

- Mental models as contributors to *mistakes*
  - *Mental Model.* A cognitive representation of the components of a system, including their properties (e.g. physical, causal) and how they relate to each other
  - Mental model of a machine can be used to simulate how the machine will behave under different condition
  - A defective mental model will lead to incorrect predictions and actions

Basics of Human–Machine Interaction

- Mental models as contributors to *mistakes*
  - *Thermostat* mental model is often defective
  - Leads to wasted heat, over-heated rooms



  - If room cold but radiator hot, do not touch thermostat!

Basics of Human–Machine Interaction

- Textbook suggests domains of cognition that might be applied in order to improve human-machine interaction
- However, examples are vague, few precise specifications
- Lacking in *actual* examples of how psychologists do help

- Next week: transit maps as a case-domain for applying psychology to information design
  - How can psychological theory help
  - How can psychology methodology help?
  - What pitfalls are there for the researcher in an applied domain?

Major Source

Davey, G.C. (Ed.). (2011). *Applied psychology*. John Wiley & Sons.

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