bio-cost

a proposal for
a new metric for evaluating products

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bio-cost = biological cost

bio-cost describes
the effort expended by an organism to reach a goal

concept emerged in 2002 from conversations
with Dr. Michael C. Geoghegan

work-in-progress with Dr. Geoghegan,
Hugh Dubberly, and CJ Maupin

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bio-cost is implicit in the language

wasting energy
spending time
paying attention
adding stress

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4 dimensions of bio-cost

wasting **energy**
spending **time**
paying **attention**
adding **stress**

4

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goals of bio-cost

to define an aggregate concept
that encompasses all the human costs
expended by a human to achieve a goal

to subsume a range of terms, vague and specific,
that relate to using products, such as *simple,
easy to use, easy to learn, less cognitive load,
intuitive, natural, emotionally satisfying, powerful…*

to create a powerful metric to guide product design

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how exactly does bio-cost
relate to product design?

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we use products to 'get what we want'

products help us complete a task
they help us reach a goal

completing a task, reaching a goal, has a cost

a bio-cost

product cost has two phases

cost of acquisition
what you paid for it
(fixed cost)

cost of use
what you pay each time you do operate it
(variable cost)

cost of use has two aspects

consumables
(e.g., power, gas, oil, paper, ink, razor blades)

bio-cost
(e.g., the human effort expended to use it)

all products require effort to use

every product has a human cost of use
every product has a bio-cost

some products have a higher bio-cost
some have a lower bio-cost

humans naturally seek to lower their bio-cost

when considering two otherwise equal choices,
rational people prefer products with lower bio-cost

so, measuring product bio-cost is important

comparing the biocosts of various options
is a strategy for improving products

and

lowering a product's bio-cost can be
a design goal

how do we measure bio-cost?

bio-cost = effort to reach a goal

reaching a goal = completing tasks

every task has multiple steps

informally, it's easy to see that every task must be
1. opened, or started, or prepared for
2. performed
3. ended, or departed, or returned-to-previous

each step adds cost

energy
time
attention
stress

how do we measure bio-cost?

energy
  physical expenditure—calories

time
  duration of time expenditure—hours:minutes:seconds

attention
  focus expenditure—what multitasking is possible

stress
  emotional expenditure—'pain' to do this versus alternatives

example 1 = mobile phone

goal = phone a colleague to confirm meeting

task's steps
1. open: dial the colleague to initiate the call
2. perform: hold the conversation
3. end: terminate the call

…and each step may be broken into smaller steps

example 1 = mobile phone

goal = phone a colleague to confirm meeting
first task step = dial the colleague

sub-steps
1. open: navigate to address book
2. perform: (a) find and select colleague's entry
          (b) press CALL key
3. end: no action required (UI reverts after 2 seconds)

   …each goal and task has the structure of a fractal

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example 1 = mobile phone

cost breakdown
1. navigate to address book
     1) access general menu
     2) click down to address book
     3) select address book
2. find and select colleague's entry
     1) press first letter of name
     2) arrow-down, arrow-down,
        arrow-down, arrow-down,
        arrow-down to correct entry
     3) press CALL
3. (no further action)

total bio-cost =

total B_{time}

total $B_{attention}$

total B_{stress}

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example 2 = PowerPoint

goal = creating a slide in PowerPoint
        that shows a 3-step process

tasks =
a) graphics = 2 shapes connected by a line
b) labels   = text to number each step

for example,

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example 2 = PowerPoint

cost breakdown
1. find and enter GRAPHICS mode
2. draw shapes
     1) draw first shape
     2) draw second shape
     3) draw line between
3. exit GRAPHICS mode

4. find and enter TEXT mode
5. type labels
     1) position cursor
     2) type first label
     3) position cursor
     4) type second label
     5) position cursor
     6) type third label
6. exit TEXT mode

B_{time}	$B_{attention}$	B_{stress}
+	+	+
B_{time}	$B_{attention}$	B_{stress}
+	+	+
B_{time}	$B_{attention}$	B_{stress}
+	+	+
B_{time}	$B_{attention}$	B_{stress}
+	+	+
B_{time}	$B_{attention}$	B_{stress}
+	+	+
B_{time}	$B_{attention}$	B_{stress}

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example 2 = PowerPoint

cost breakdown
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4. find and enter TEXT mode
5. type labels
     1) position cursor
     2) type first label
     3) position cursor
     4) type second label
     5) position cursor
     6) type third label
6. exit TEXT mode

total bio-cost =

total B_{time}

total $B_{attention}$

total B_{stress}

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how can we measure bio-cost?

energy
  energy consumption not substantial—can be ignored

time
  literal hours + minutes + seconds of duration for a given task

attention
  subjective observations in focus groups, using variations in design

stress
  biometrics, or simply have user subjectively rank designs, lowest to highest stress or 'hassle'

bio-cost
encompasses other design metrics

GOMS—goals, objects, methods, selection rules
'Information Efficiency'
Fitt's Law
Hick's Law*

   …and provides a broader, more comprehensive
      framework for discussing product metrics

* See Raskin, *The Humane Interface*, 2000.

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bio-cost is only half the equation

people evaluate products in terms of 'utility'
utility is the ratio of gain to cost

$$\text{utility} \quad = \quad \frac{\text{gain from reaching the goal}}{\text{cost of achieving the goal}}$$

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utility function

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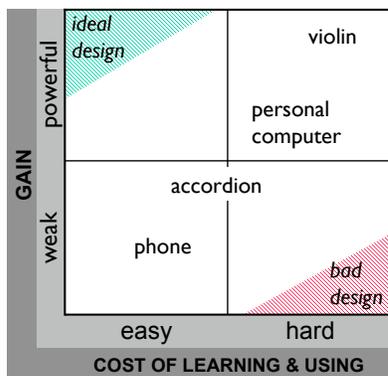
designing ideal interfaces

easy to learn and powerful to use

but how do we know when we succeed?

we must have:
· a metric of ease of learning = biocost
· a metric of ease of using = biocost
· a metric of gain or benefit = ??

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how can gain be measured?

$$\text{utility} \quad = \quad \frac{\text{gain from reaching the goal}}{\text{cost to achieve the goal}}$$

$$= \quad \frac{\text{overall gain}}{\text{bio-cost}} \quad = \quad \frac{\text{getting what I want}}{\text{bio-cost to get it}}$$

$$= \quad \frac{\text{measurable outcome}}{\text{time + attention + stress to achieve the outcome}}$$

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example of outcome = violin

playing the violin
· holding it correctly
· playing accurate pitch across nearly 4 octaves against a specific score
· using the bow for attack/release/nuance
· coordinating between two hands
· imbuing sound with emotion, expressiveness

· …doing all this in *real-time* according to the tempo of the musical piece

example of outcome

side comment

an individual violinist supports an ensemble, that supports a dance, that builds a community, that shares the burden of shelter and safety

many outcomes extend far beyond the individual
individual actions may achieve goals for groups
agreeing to share bio-cost is common to all social animals

cost of learning to play + cost of playing provides huge gains, such as participation, appreciation, belonging, self-esteem, and community

(see back-up slides for basic exploration of sharing bio-cost)

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example of outcome = software

creating a slide with PowerPoint
- learning the menus and functions
- using the functions to create objects and text
- using functions that adjust objects and text

…building an internal model of the capabilities and processes of using the product

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## measuring outcome

capturing the complexity of the outcome

= bits of information required to specify control of the interface
- from Shannon's Information Theory
- yes vs. no = 1 bit   1 of 256 shades of color = 8 bits
- specification of all movements required to create this slide
  - perhaps thousands of bits

= time required to achieve the outcome
- real-time case (music performance)
  - must occur within given time constraint
- asynchronous case (software user interface functions)
  - total time taken determines *efficiency*

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example 3 = mobile phone

dialing colleague ⟶ *information measure*

1. navigate to address book
  1) access general menu
  2) click down to address book
  3) select address book
2. find and select colleague's entry
  1) press first letter of name
  2) arrow-down, arrow-down,
    arrow-down, arrow-down,
    arrow-down to correct entry
  3) press CALL
3. (no further action)

1. navigate to address book
  1 of 8 functions on main menu
  = 3 bits

2. find and select colleague's entry
  1 of 250 entries in address book
  = 8 bits

3. (no further action)
  = 0 bits

$$\approx \frac{3 \text{ bits} + 8 \text{ bits} + 0}{12 \text{ seconds}} = \frac{1 \text{ bit}}{\text{second}}$$

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example 3 = mobile phone

voice dialing

1. navigate to voice entry mode
  1) click external voice-entry button

2. find and select colleague's entry
  1) speak colleague's name

3. (no further action)

$$\approx \frac{3 \text{ bits} + 8 \text{ bits} + 0}{2 \text{ seconds}} = \frac{6 \text{ bits}}{\text{second}}$$

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example 3 = mobile phone

finger dialing

1. navigate to address book
  1) access general menu
  2) click down to address book
  3) select address book
2. find and select colleague's entry
  1) press first letter of name
  2) arrow-down, arrow-down,
    arrow-down, arrow-down,
    arrow-down to correct entry
  3) press CALL
3. (no further action)

voice dialing

1. navigate to voice entry
  1) click external voice-entry button

2. find and select colleague's entry
  1) speak colleague's name

3. (no further action)

$$\frac{1 \text{ bit}}{\text{second}} \ll \frac{6 \text{ bits}}{\text{second}}$$

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metric summary

+ time
+ attention
+ stress

Learning

$B_L = B_t + B_a + B_s$
amortized across all future use

+ time
+ attention
+ stress

Using

$B_U = B_t + B_a + B_s$
for a given outcome

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why bio-cost is important

if we think about bio-cost, we can lower it

lowering bio-cost frees humans to do more
lowering bio-cost increases choices

lowering bio-cost creates a more humane world

lowering bio-cost is an ethical motivation
in the design process

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bio-cost

feedback welcome
pan@pangaro.com

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rigor in applying bio-cost

rigor in applying bio-cost means having a consistent measure and an objective process to apply it

product development can use metrics based on 'biocost' to compare alternative designs. while not the only criteria for product evolution, 'following the bio-cost' will cause product improvements that the user articulates as 'easier to use', 'simpler to learn', and others emotional components that are related to the time, attention, and stress required to learn and use the product

bio-cost metrics are being developed from applicable and prescriptive cybernetic theories that quantify models of system viability and collaboration

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how do biology and bio-cost relate?

the nervous system
    explores strategies that increase variety
    uses feedback to steer through disturbances
    naturally seeks harmony as a means to conserve bio-cost

survival is enhanced by reducing bio-cost because
    less bio-cost means more energy for more strategies
    more strategies mean more variety
    more variety means better longevity, survival

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bio-cost is coupled to survival

primary goal of organism is to persist, to survive
survival takes biological energy

this 'biocost' is physical **energy** and also mental energy

mental energy is required to perform tasks of survival, and also to think about more efficient ways to perform those tasks

mental energy means **attention** paid to perform the task, or think about how to perform the task

of course, thinking and doing take **time**. sometimes it seems as though there isn't enough time

not having enough time adds **stress** to the bio-cost

bio-cost is **energy, attention, time, and stress**

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pluses and minuses of achieving a goal
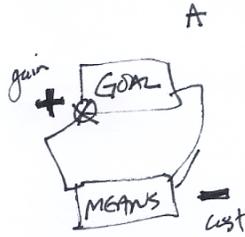
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bio-cost equation—single participant
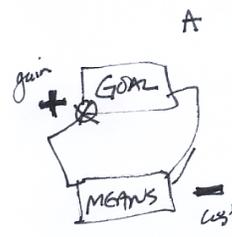
$$\text{utility for A} = \frac{\text{gain from achieved goal}}{\text{bio-cost to achieve goal}}$$

first canonical form

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bio-cost equation—cooperative participants
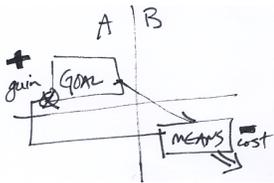
$$\text{utility for A} = \frac{\text{gain from achieved goal}}{\text{cost to pay B to achieve goal}}$$

$$\text{utility for B} = \frac{\text{gain from payment to achieve goal}}{\text{bio-cost to achieve goal}}$$

second canonical form

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bio-cost equation—collaborative participants
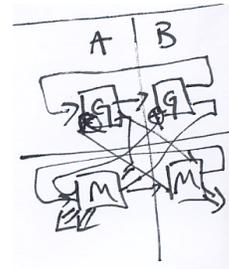
$$\text{utility for A} = \frac{\text{gain from achieved goal}}{.5 \times \text{cost to personally achieve goal}}$$

$$\text{utility for B} = \frac{\text{gain from achieved goal}}{.5 \times \text{cost to personally achieve goal}}$$

third canonical form

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net conservation of bio-cost
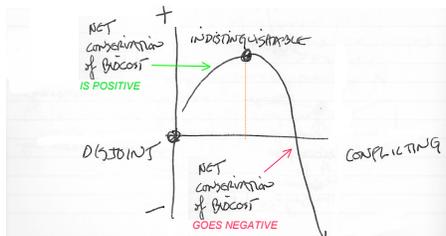
i. A'S GOALS AND B'S GOALS ARE INDISTINGUISHABLE. A and B fully may collaborate on achieving their shared goals, and thereby conserve bio-cost. NET conservation of bio-cost is at a positive maximum for these goals.

ii. A'S GOALS AND B'S GOALS ARE DISJOINT. A and B do not share goals and do not conserve bio-cost through collaboration. They can, however, choose to cooperate if one helps to achieve the other's goal.

47 iii. A'S GOALS AND B'S GOALS ARE CONFLICTING. Actions taken by A or B to achieve their goal will conflict with the other's goals or actions. Rather than conserve bio-cost, the interaction adds bio-cost.

bio-cost

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