THE WELL-DESIGNED CHILD

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• The world into which a human is born is complex. W
discuss some of the complexities, concentrating on on
3-d semi-permanent, movable objects.

• Evolution has equipped a baby with some innate kno
edge of the world. That works better than starting a
blank slate.

• Consider a well-designed logical robot child (WD
Mostly it will have the innate abilities we conjecture
children have, but sometimes we can do better.

THE LOCKEAN BABY

• John Locke 1693: The baby starts out as a blank sl
It builds its knowledge by inferring associations am
stimuli.

• Since 1950 people proposed to start with a Lock
blank slate baby machine and have it learn from its ex
rience.

• Starting from the blank slate, I'll bet it's a leng
process to infer the existence of 3-d objects. I do
think anyone has made an AI system that can do it.

• A billion years of evolution has provided us with pr
good prejudices about the world far better than a bl
slate. Our robot child should also have them

THE WORLD IS COMPLICATED

• The world's structure is not directly describable in te
of the input-output relations of a person. The basic str
ture of the world involves elementary particles on t
scales of 10^{-25} seconds, but intelligence only evolve
structures of more than 10^{23} elementary particles.

• Even at the level at which a small child can perceive
the world is extremely complicated. Here are some of
complications.

• Reality and appearance Animals and humans don't p
ceive the structure of our environment directly. Sen
have evolved to give *partial* information about obje
and their relations.

• The world is 3-d, but our senses react to surfaces.

MORE COMPLICATIONS

• semi-permanent objects Much of the world consists three-dimensional objects that have masses, mome compliances, hardnesses, chemical composition, shap outer surfaces with textures and colors, are often mad identifiable parts which sometimes move relative to e other. A particular object can disappear from percept and reappear again.

Note that the structure and location of an object in world are more persistent than its appearance and lo tion in the visual field or relative to the hands.

• temporal structure The environment of a child ha
complex temporal structure. Some items change in s
onds, others last for hours, days, or years. Babies
in the present. The concepts of *tomorrow* and *yester*
are not learned right away.

• causality Events cause changes in objects and their
lations and cause other events.

STILL MORE COMPLICATIONS

• solidity Objects are solid and do not ordinarily penetr
one another. Some are rigid and some are flexible.

• gravity Unsupported objects fall to a lower surface.

• kinds of objects Objects have kinds, and objects
the same kind have properties associated with the k
Babies are ready very early to learn what kinds there

• natural kinds Many of the objects a child encount
e.g. lemons, belong to *natural kinds*. The objects o
natural kind have yet undiscovered properties in comm
Therefore, a natural kind is not definable by an *if-a*
only-if sentence formulated in terms of observables.

• relations Objects not only have individual proper
and belong to kinds, but objects and kinds have relati
with one another. At least some ternary relations s
as betweenness are basic. Also "A is to B as C is to
seems to be basic. In its numerical use, it reduces
the equality of two fractions, but the quaternary relat
seems to be basic in common sense usage.

WHAT DO BABIES KNOW AND WHEN?

- Q: If the world is so complicated, how can babies anything purposeful?

- A: They know simple cases of phenomena.

- There's good psychological evidence that they have innate knowledge of solid objects that continue exist even when out of sight. How do they remember an obj that has gone out of sight so as to recognize it whe reappears?

- They are ready to ascribe purposeful action to hum and animals and to try to influence them.

• the principle of mediocrity (from the astronomers) C
child is like other children. This lets it reason in b
directions.

• persons Some objects are animate and have purpo
analogous to those of the child. They can be influen
but are sometimes to be feared. Defects in innate und
standing of persons, e.g. autism, harm the child.

WHAT DO WE WANT IN A WELL-DESIGNED ROBOT CHILD?

- Distinguish appearance from reality

- natural kinds Natural kinds don't have if-and-only-if d
initions. There may always be more properties to
learned. To a small child, all kinds are natural. T
robot child should think in terms of natural kinds.

- three-dimensional objects These are more stable t
the perception of them by any sense.

- perceive motion as continuous

- actions and their effects

• recognize parts Recognize parts of an object and t
relations to the others. It would be interesting to hav
grammar of 3-d physical structure analogous to that
sentences.

• focussed curiosity

• grammar of goal regression To do A, I need to d
first, and to do B, I need to do C first.

• introspection Children begin to do this by age 3, d
well by age 5. The WDC needs it.

THE SPELKE EXPERIMENT

This psychological experiment exhibits abilities of hur
babies we want in the WDC.

Elizabeth Spelke described a number of experiments t
she and others did to discover and verify innate me
abilities. The technique uses the fact that a baby
look longer at something surprising than at someth
that seems familiar.

Here's one that was first done in 1973 and was repea
by Spelke in 1993 with two months old babies. Th
are experimental babies and control babies and the
periment has two phases. In the first phase the con
babies are shown nothing. The experimental babies

an object go behind a screen and shortly another ob
emerges on the other side of the screen. The timin
such as would be appropriate if the first object str
the second object and knocked it from behind the scre
The babies are shown the phenomenon enough times
get bored with it and stop paying attention.

In the second phase of the experiment the screen is
moved. There are two variants. In the first variant,
first object strikes the second and knocks it onward.
the second variant the first object stops short of the s
ond, but the second object takes off as though it
been struck. The control babies look at both variants
the same amount of time. The experimental babies l
longer at the second variant.

The conclusion is that the experimental babies infe
that the first object had struck the second when the ev
occurred behind the screen. When the screen was
moved, they were not surprised when the expected ev
was shown to occur but were surprised and looked lon
when this expectation was not met.

The conclusion is that babies have innate expectati
about dynamics. For details see Spelke's 1994 articl
Cognition, *Initial knowlege: six suggestions*.

THE WELL-DESIGNED CHILD AS A LOGICAL ROBOT

- Not even a sketch of a design—just some ideas.

- Appearance and reality

$Appears(appearance, object)$ is too simple except in a l
ited context, but children think in limited contexts.
$Holds(Appears(person, appearance, object), s)$ says more
is suitable for referring to the child from the outside.

CONTEXTS

• The correctness of a child's beliefs and references objects depends on context. Children change cont frequently.

• When looking at a child's ideas from the outside, can use the theory of contexts as objects introduced my *Notes on formalizing context*. In that theory $Ist(c, p$ true if the proposition p holds in the context c. $Value(c$ is the value of the expression exp, e.g. $Color(Block1)$ context c.

• $Value(Beliefs(Child1, S0), Color(Block1)) = Red$ ass that in the context of Child1's beliefs in situation s, Blo is red. The context theory lets us *enter* the cont $Beliefs(Child1, S0)$. Then we have $Color(Block1) = R$

THREE CHALLENGES AND A CONCLUSION

• Make a robot baby that can do the Spelke experim honestly. But what's honestly? It may start know about collisions and knowing about occluded objects, at least it shouldn't start with knowledge combining two.

• Its contexts should change like those of a baby.

• It should properly relate 2-d appearances to 3-d rea and also relate tactile appearances to reality. Here' puzzle.

• What babies know presents challenges to AI—to A all schools.

- This talk is partly based on the manuscript http://www-formal.stanford.edu/jmc/child.html.