

Principals of Object Perception

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Summary

Infants perceive object by analyzing tree-dimensional surface arrangements and motions. Their perception is not accord with a general tendency of maximizing figural goodness or to attend to non accidental geometric relations in visual arrays. Object perceptions are according with principles of motions of material bodies. Infants divide perceptual arrays into types of units that:

- ◆ Move as connected wholes
- ◆ Move separately from one another
- ◆ Tend to maintain their size and shape over motion
- ◆ Tend to act upon each other only on contact

The findings suggest that representation of object unity and boundaries is interposed between representations of surfaces and representation of familiar objects. The process of constructing representation may be related by physical reasoning.

The article consists of **2 proposals**:

- ◆ **First** is substantial: In perception developing through experience situations, without previous instruction, development enrich perceptual abilities, but not fundamentally change them.
- ◆ **Second** is methodological: In above situations, studies on origins and early development of perception can describe perception in early stage.

These 2 proposals came from discussions on beginning of perceptual ability to organize arrays of surfaces in **unitary, bounded** and **persisting** objects.

Aims

Describing early processes of infant's perception of objects through experiment studies on and comparing them with adult's perception.

Extracting and defining principles, by which infants perceive objects.

Give new light on understanding of physical knowledge and human reasoning through these principles.

Addressed problems

The article is analyzing early development of infant's perceptual ability; abilities to organize visual arrays into unitary, bounded and persisting objects; Gestalt perception in infancy and its development; perception of object's motion; Haptic perception of objects; apprehension of moving object identity.

I. Perceiving Objects

The author is studying young infants' perception of objects in complex displays. E.g. adjacent, hidden behind or moving objects

- ◆ The reasons that this article is focusing on unordered and changing visual arrays are:

1. Usually objects rarely stand against homogeneous background

2. Apprehending of objects is process beyond the immediately visible layout, to capture underlying arrangement, rising that layout
3. Ability to organize unexpected, cluttered, changing arrays to objects is mysterious. No mechanical system can accomplish it in general manner. May be it is generally impossible, but only unity, boundaries and persistence of objects of particular kinds.

The previous view on this ability is that there is no separate stage of segmentation process in object recognition procedures, which categorize and find boundaries by fitting models familiar objects to not segmented representations.

◆ Contrary to this view author suggests that general segmentation process serve to divide visual arrays into objects. For **inexperienced** user this permits to apprehend physical objects as persisting bodies with internal unity and stable boundaries. This process may facilitate recognition of **experienced** perceivers, because they have limited number of models, to which models can be matched. Studies of infants perception is well matched, because they lack models for most categories of objects. This research suggests that human process of apprehension occur relatively late in visual analysis, after information for 3D surface arrangements and motions.

◆ The process is according with 4 principles for human perception of objects and human reasoning of objects motion:

1. Cohesion
2. Boundedness */property of to be bounded/*
3. Rigidity
4. No action at a distance

◆ The article is divided on 4 parts:

1. Discussion of negative findings – Infants do not perceive objects by general tendency of giving simplest, most regular organization of visual experience
2. Positive findings – Young infants perceive objects as unitary, bounded, and persisting bodies by analyzing surface arrangements and motions
3. Propose of partial account of findings in terms of 4 principles of object motion
4. Implication of findings for theories of object perception by adults and for artificial vision systems. The ways perception change or not with knowledge growth

II. Gestalt Relations and Object Perception in Infancy

Two traditional proposals are:

1. Prägnanz principle of **gestalt** psychologists – The organization of visible surfaces into objects

*Prägnanz law says that we try to experience things in as good a **gestalt** way as possible. "Good" can mean such as regular, orderly, simplistic, symmetrical, etc.*

2. **Empirists'** understanding of object perception – principles of sensation and association. Infants first perceive only visible fragments of an array. Then they learn that certain properties of visual arrays are related to certain properties of bodies.

Empirists' theory /empiristic theory/ of visual perception is considering human retina processes, perception of color and brightness, location, luminance, etc. It is developed by H. Helmholtz.

Infant Perception of Object Unity

Testing these theories with prelocomotor /before locomotion abilities/ infants.

The question is: How infants perceive an object that is partly hidden?

E.g. **Figure 1.** Regular shaped object is center occluded. Suggested perceptions /test displays/ are showed below.

Experiment 1.

4-months-old infant's perception of partly hidden objects.

Steps of used **habituation method** in experiment 1.

- ◆ Series of trials until time spend looking at display is 50% reduction of looking time.
- ◆ Then shown two displays with different patterns
- ◆ In 6 alternating trials – begin when infant looked at the display and ended when looked away
- ◆ For baseline – 6 test trials without habituation
- ◆ Then compared. Compared to base line - longer looking is on display, which is not habituated /not percept/

Habituation method and some variations of it are used for all experiments in paper. This method is based on the assumption that when a stimulus is presented repeatedly, any response will gradually decline with trials.

- ◆ *The infants are presented with a single stimulus for a series of discrete trials, until habituation. Then a new stimulus is introduced.*
- ◆ *Trial ends when infant looks away for a specified amount of time /e.g. 2s/.*
- ◆ *A few second later new trials begin with the same stimulus, until again infant looks away again.*
- ◆ *Over trials infant looks less and less at the stimulus – that is the habituation process.*
- ◆ *Habituation criterion is typically when infant reduced responding time by 50% of initial trial.*

Figure 2 (a to l). Different occluded /overlapped/ displays, used in experiment 1

Aim is description of processes of infant's perception of unity of partly hidden and hidden moving objects.

Method and setting

It is used different occluded displays from Figure 2 by habituation method. Then it is tested infants reaction on fragmented and connected rod.

Results

Only objects from Figure 2 (a), (b), (e) and (f) are percept like connected rod, the same like adults except (e) affected by Gestalt.. Example (l) has no perception for connected body, which is opposite compared to different study for 5-months-old infants.

Figure 3. Results: Looking time of 3 motions for object (a) and (f) from Figure 2 .There is reliably lower looking preferences to fragmented rod.

Discussions

Findings are not consistent eider to Gestalt theory or Empirists theory.

Not like Empirists – Infants do not perceive object to end at occluded begins. Contrary to Gestalt – not grouping visible surfaces in maximally simple and regular:

- ◆ They perceive as one if the ends move together behind occluding object.
- ◆ Vertical, lateral and translation in dept are the same
- ◆ Not affected by object configuration properties – Figure 2e as 2a
- ◆ With stationary object – responded equally to connected and fragmented objects

These contrasts to **adults** – responses are affected by **Gestalt**, grouping occluded in the simplest possible form.

Infants are affected by object's **motion**.

Infant Perception on Object Boundaries

Experiment 2.

3- to 5-months-old infant's perception of objects boundaries. Summarizes also experiment results from previous authors articles.

Aim is description of processes of infant's perception of objects boundaries.

Method and setting

It is used 2 objects from Figure 4 in varieties of arrangements are presented to infants by habituation method. Then it is tested if infants' perception is for one or 2 objects

Figure 4. Depiction of displays for perception of object boundaries. Objects (c, e, g and h) are separated in dept.

4 methods are used for investigating perception of object boundaries:

- ◆ Object directed reaching
- ◆ Apprehension of number of objects by habituation-to-number method. Habituation to one or two objects
- ◆ Violation of objects integrity and boundaries /Surprise method/
- ◆ Habituation to overlapping objects. Display with new arrangements.

Results

Objects from Figure 4 (a), (c), (e), (g), (i), (k) and (l) are percept as two separated objects. All other couples of objects are percept as one object.

Discussions

All experiments show that young infants perceive objects boundaries by detecting **surface motions** and **surface arrangements**.

Figure 4i – Moved, but touched

Figure 4a, 4c, 4e – 2 stationary objects as separate units when they were spatially separated on any dimension.

Figure 4b and 4d – by 3-months infants like one unit.

This is contrasting with **adults** – they are detecting not only **surface motions and arrangements**, but also **surface colors, textures and forms**.

Detection versus Use of Gestalt Relations

Infants fail to respond to gestalt relationships, but not from limits on visual acuity. They for example detect misaligned contour – Gestalt relation of good continuation.

They are sensitive to homogeneity and heterogeneity of surface coloring. And figural goodness as symmetry.

Despite that, they **not** appear to use these relationships in organizing **surfaces to objects**, they are guided only by surface properties and surface relationships, they can detect.

Gestalt Relations and Non-Accidentalness

Above mentioned experiments are motivated by Gestalt approach to object perception, but they are relevant to newer approach to perception - principle of **non-accidentalness**. E.g. Co linearity and parallelism are unlikely to occur in retinal arrays through an accident of viewpoint. This newer approach of non-accidentalness is developed by the author, contrary to previous views of the problem.

Development of Gestalt Perception

Experiment 3.

5- and 7-months infants perceive of partly occluded object by gestalt relations.

Aim is description of processes of infant's perception characteristics of partly occluded object by gestalt relations of good continuation and similarity.

Method and setting

It is used different occluded displays from Figure 5 by habituation method. Then it is tested infants reaction of one or two objects.

Figure 5. Used nonsense center-occluded forms.

Results

5-months infants have equal response to 2 test displays, but 7-months infants show in case (a) preferences to one object, in case (b) equal. That means 5-months infants still have not developed Gestalt perception for good continuation.

Another research is cited, where 2.5 years old infants are responding like adults, using Gestalt perception in both displays.

Discussions

There is no single moment when humans begin to perceive objects by figural goodness.

III. Object Perception as a Later Process

In next experiments author found that infants perceive the unity and boundaries by detecting spatial arrangements and motion of surfaces.

Proximal versus Distal Motion in the Perception of Object Unity

In previous experiments infants detect unity of center-occluded object by detecting any translation motion.

Experiment 4.

Investigating 4-months-old infant's perception of center-occluded rod.

Aim is description of processes of infant's perception characteristics of center-occluded rod in cases of moving rod or/and subject.

Method and setting

Figure 6. Top view of test displays. Arrows are indicating motion.

Results

Infants in proximal motion condition show equal response to broken and complete test rods.

Infants in distal motion condition showed the same looking patterns like previous experiment.

Figure 7. Findings.

Discussions

This is evidence that:

- ◆ Mechanisms of object perception operate on representations of **distal motion** of surfaces, not on representations of proximal motions.
- ◆ On first stage infants perceive the arrangements and motions of surfaces in 3D layout. Then this representation serves as input to object perception process, which organize the layout into connected bodies that move as wholes.

Haptic Perception of Object Unity and Boundaries

Experiment 5.

Investigating 4-months-old infant's haptic mode of perception of unity and boundaries.

Aim is description of processes of infant's haptic mode of perception of objects' unity and boundaries.

Method and setting

Figure 8. Displays and apparatus. Two rings, placed under cloth.

After initial habituation to rigid motion (a) or independent motion (b), are showed visual test displays from Figure 8

Results

Infants perceived commonly /rigid/ moving rings like a single object.

Discussions

That means that motion specify unity and boundaries of objects in infants' haptic perception.

Experiment 6.

Investigating 4-months-old infant's haptic mode of perception of unity and boundaries, affected by figural goodness.

Aim is description of processes of infant's haptic mode perception of objects' unity and boundaries and their affection by figural goodness.

Method and setting

The same display as Experiment 5, but rings are differing or not in:

- ◆ Substance /wood and rubber/
- ◆ Weight /heavy or light/
- ◆ Texture /rough or smooth/
- ◆ Shape /square and round/

Results

Infants perceived commonly /rigid/ moving rings like a single object.

That show infants are **not effected by figural goodness**, contrast to **adults**, effected both by motion and figural goodness.

Adult's haptic mode is affected by gestalt.

Discussions

In summary infant's haptic perception is as they see them.

Apprehension of Object Identity

Experiment 7.

4-month-old infants' persisting identity of objects that move fully out of view.

Aim is description of processes of on infant's perception characteristics of identity of objects that move fully out of view.

Method and setting

- ◆ Used display is 2 objects moving behind 2 screens
- ◆ In first – one object moved continuously and disappeared behind 2 screens in turn
- ◆ In 2nd – the same, but no object appeared between screens /pause/
- ◆ 2 groups are habituated to each event

Figure 9. Continuity or discontinuity of the path of objects motion

Results

Adults' reaction on Figure 9

(a) – One object, (b) – 2 objects moving continuously on the sides of display

Infants – Figure 9

- ◆ Infants habituated to (a) Continuous event results more to One-object event, respectively to (b) Discontinuous to 2 object
- ◆ With baseline control condition – in Discontinuous condition reliably exceed baseline, but in Continuous – no difference.

Discussions

In visible discontinuity infants perceive 2 objects – in any speed, regardless to smoothness and regularity. According to Gestalt principles, adults perceive one object in case of appropriate to visible speed. Gestalt principles not influenced young infant's response to object.

IV. Principles of Object Perception

In summary infants can sometimes perceive:

- ◆ Unity of hidden objects
- ◆ Boundaries of adjacent objects
- ◆ Identity or distinctness of moving out of view objects

The mechanisms are:

- ◆ Infants take representations of 3D surface arrangements and motions
- ◆ They are amodal /non modal/
- ◆ They give representations of parts or states of object not seen directly

The author proposes that:

- ◆ Infants first forming a representation of visible surface layout.
- ◆ Surface points are organized, using “connected surface points” for perception of the object unity.
- ◆ Perceived layout is divided to unitary, bounded and persisting objects, by mechanisms by **principles cohesion, boundedness, rigidity, and no action at a distance**:
 - **Cohesion principle** – all points on object exist continuously during observation. If motion of point is continuous, then all points move on connected paths over space and time. /Fig. 9b/
 - **Boundedness principle** – 2 surface points lie on distinct objects if no path of connected surface points links them. /Fig. 4b,4d,4f,4j/ Two objects cannot contain the same surface point, two objects cannot be at same place and time, cannot interpenetrate.
 - **Rigidity principle** – 2 surfaces having different rigid motions are perceived as different, unless there is detected directly body with non rigid center /Fig. 4g, 8b/.
 - **No action at a distance principle** – 2 surfaces with same rigid motion are connected, if there is no detectable separation between them /Fig. 2a, 2e, 2f, 4h, 8a, 4l/

Concerning this two aspects are mentioned:

1. The **principles cohesion, boundedness, rigidity, and no action at a distance** do not permit a complete segmentation of visual arrays in objects. Must be supplemented by further process / e.g. recognizing particular kind of objects/.
2. There is a link between process of perceiving objects and process of reasoning about physical world. This is focusing on **topological** properties – bodies move as wholes, on connected paths, not interpenetrate, not deform and separately from one another.

Abilities to perceive are related to abilities to reason about objects and behavior. From past research, young infants' inference objects motion to principles by infants perceiving object unity, boundaries and identity.

V. Developmental Changes in Object Perception

What is connection with adults' perception and machine vision?

The author suggests that development does **not bring fundamental changes** in object perception. In fact, new ways of apprehending object **enrich** infant's **earlier developing abilities**. This can shed light human perceptual process or machine vision.

Development of Gestalt Perception and Object Recognition

The clearest change in object perception is **emerging ability** to perceive objects with **Gestalt relationships**. Infants need new ways of to perceive objects, because of limited initial abilities.

But according gestalt psychologists these relations cannot be learned, because of paradox “experience error”. The learning of scene depends on how one organizes it.

Q: **How** children learn Gestalt principles of organization?

A: If infants **learn to organize bodies in cohesive, bounded and independently** movable, then will be able to perceive **surrounded object in certain** good conditions.

When observe properties of an object like texture and shape, they discover that many objects simple shapes, smooth color etc., this leads to perceive objects according Gestalt relations.

E.g. from past research between 4 and 5-month-old infants is developed perception of center occluded photo of human face – unity of partly hidden object.

Initial principals for organizing the perceptual world are enriched with growth of knowledge.

Cohesion, boundedness, rigidity, and no action at a distance are central properties for adult viewers.

Mature Process of Perceiving Objects

If development enriches object perception without changing it, then studies of infancy can shed light on adults object perception.

3 proposals about mature process of object perception:

1. Relation of object perception to surface perception – Visual arrays is organized into objects after they are represented as a 3D layout of surfaces. Object perception is far from elementary process of edge-detection and texture segmentation. Object segmentation occurs after perception of surface distance and motion.

2. Relation of object segmentation and object recognition – Process of perceiving object operates before processes for recognizing objects of particular kinds. General process of object segmentation could facilitate the task of object recognition by limiting the number of potential matches of models and enable to develop models for new kind of objects.

3. Relation of object perception with physical knowledge – Object perception accord with principals with reasoning about physical world. Infants percept with principals of cohesion, boundedness, rigidity and no action at a distance when predict how will move hidden object, etc. Adults also honor these principals.

It is possible that principals of infants perception to be deeply embedded in human thinking. This may contribute to understanding physical knowledge.

Summarized experiments

Exp.	Subjects /-months/	Focused on	Method and setting	Results	Discussions, based on results. Comparison to adults.
1*	4	Perception of partly hidden objects	Different occluded displays from Figure 2 by habituation method	Only objects from Figure 2 (a), (b), (e) and (f) are percept like connected rod, the same like adults, except (e) affected by Gestalt.. Example (l) has no perception for connected body, which is opposite compared to different study for 5-months-old infants. Figure 3.	Not consistent either to Gestalt theory or Empirists theory. Infants: Perceive as one if the ends move together behind occluding object; Different translations are the same; Not affected by object configuration; Not perceiving stationary object These contrasts to adults , grouping occluded in the simplest possible form. Infants are affected by object's motion .
2**	3 to 5	Perception of object boundaries	2 objects from Figure 4 in varieties of arrangements by habituation method.	Objects from Figure 4 (a), (c), (e), (g), (i), (k) and (l) are percept as two separated objects. All other couples of objects are percept as one object.	Infants perceive objects boundaries by detecting surface motions and surface arrangements . This is contrasting with adults – they are detecting not only surface motions and arrangements , but also surface colors, textures and forms .
3	5 and 7	Gestalt perception of partly occluded object	It is used different occluded displays from Figure 5 by habituation method.	5-months infants have no difference, but 7-months infants show in case (a) preferences to one object, in case (b) equal. 2.5 years old infants are responding like adults, using Gestalt perception in both displays.	That means 5-months infants still have not developed Gestalt perception for good continuation . Adults are using Gestalt perception in both displays. There is no single moment when humans begin to perceive objects by figural goodness.
4	4	Perception of center-occluded object /rod/	Different test displays from Figure 6 by habituation method. Arrows are indicating motion.	Infants in proximal motion condition show equal response to broken and complete test rods. Infants in distal motion condition showed the same looking patterns like previous experiment. Figure 7.	Mechanisms of object perception operate on representations of distal motion of surfaces, not on representations of proximal motions.
5*	4	Haptic perception of unity and boundaries	Two rings, placed under cloth. Habituation to rigid motion (a) or independent motion (b).	Infants perceived commonly /rigid/ moving rings like a single object.	That means that motion specify unity and boundaries of objects in infants' haptic perception.
6*	4	Haptic percept. of unity and boundaries /factor influence/	The same display as Experiment 5, but rings are differing in: Substance, Weight, Texture, Shape	Infants perceived commonly /rigid/ moving rings like a single object.	Infants are not affected by figural goodness , contrast to adults , affected both by motion and figural goodness. Adult's haptic mode is affected by gestalt. Infant's haptic perception is as they see them.
7*	4	Persisting identity of objects that move fully out of view	2 objects moving behind 2 screens. Continuity or discontinuity of the objects path. Habituation method.	Figure 9. Infants habituated to (a) Continuous event results more to One-object event, respectively to (b) Discontinuous to 2 object. With baseline control condition – in Discontinuous condition reliably exceed baseline, but in Continuous – no difference.	In visible discontinuity infants perceive 2 objects – in any speed, regardless to smoothness and regularity. According to Gestalt principles, adults perceive one object in case of appropriate to visible speed. Gestalt principles not influenced infant's response to object.

* cited or interpreted from previous publications of the author; **a part of experiment is from previous publication of the author