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Do manual gestures help the learning of new words? A review of experimental studies

Abstract: We all produce manual gestures when we speak and these gestures have been shown to play an important role in the act of communicating. The aim of this chapter is to further investigate the specific role played by manual gestures in combined semantic and lexical learning by reviewing the experimental evidence provided by the literature. Nineteen articles met our selection criteria. They explore the effect of manual gestures in learning new words in both typically developing and speech and language impaired participants. Even though it was not an exclusion criterion, none of the studies dealt with adults: all tested children of various ages. Several research questions are addressed: 1. Is there a general advantage of using manual gestures in learning new words? 2. Is there a specific effect of manual gestures vs. other additional cues? 3. Is there a differential effect on learning to comprehend and to produce the newly learned words? 4. Do different types of gesture have different effects? 5. Does testing at different points in time yield different results? 6. Does producing the gesture during training matter? 7. Do manual gestures help generalize the use of newly learned words to new contexts? Hypotheses on the reasons why gestures would play a positive role for word learning are then suggested.

Keywords: gestures, memory, novel word learning, child language acquisition, speech production, speech and language disabilities

1. Introduction

Manual gestures are part of communication. We all move our hands and arms while we speak and researchers have argued that these gestures "are an integral component of the communicative act of the speaker" (Kendon, 2004; p. 359). According to the growth point theory, gestures and speech stem from a common thought process (McNeill, 1992; McNeill & Duncan, 2000; McNeill et al., 2008). They would even be controlled by the same motor system (Gentilucci & Dalla Volta, 2008). The brain integrates both signals when perceiving a communicative act (e.g., Özyürek et al., 2007) even though the networks involving the processing of the two modalities do not overlap completely (Bernardis, Salillas, & Caramelli, 2008).

Before being able to speak, babies begin communicating intentionally using gestures, more specifically pointing gestures. This is probably due to the fact that manual gestures are mastered more easily by infants than speech (e.g., Goodwyn & Acredolo, 1993). Gestures are indeed holistic whereas speech is sequential. From a motor point of view, the hands are easier to control than the oral/vocal system required for speaking. One could then argue that manual gestures could be used by infants simply before they can speak and not actively play a role in speech and language development. Iverson and Thelen (1999) proposed a model describing the co-development and entrainment of the arm/hand and oral/vocal motor systems from birth to around 18 months. The model describes how the two systems and their development are closely related. The first gestural communicative acts have also been shown to predict the onset of the first words (e.g., Iverson & Goldin-Meadow, 2005; Goldin-Meadow, 2007). Gesture use is predictive of later vocabulary size (Rowe, Özçalışkan, & Goldin-Meadow, 2008). The type of gesture even predicts the class of words acquired (Kraljević, Cepanec, & Šimleša, 2014). Later on, babies start combining gestures and words to create utterances and this stage has also been shown to be predictive of the first multi-word utterances (e.g. Capirci et al., 1996; Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005; Rowe & Goldin-Meadow, 2009). Iverson, Capirci and Caselli (1994) showed that, as late as 16 months, the majority of the children they observed still had a clear preference for gestural communication, even though they had equivalent gestural and verbal repertoires (see also, Caselli et al., 2012). From two to 3;6 years of age, it has been shown that the production of iconics and beat gestures was correlated with language development (Nicoladis, Mayberry, & Genesee, 1999; Mayberry & Nicoladis, 2000) and more specifically with verbal vocabulary development (Acredolo & Goodwyn, 1988).

Taken together, this research suggests that children naturally produce manual gestures to communicate and that these gestures play a role in language acquisition, not only before speech onset but also later (Özçalışkan & Goldin-Meadow, 2005). Purposely encouraging infants to communicate using symbolic manual gestures from 11 months of age has been shown to have positive effects on later language development (Goodwyn, Acredolo, & Brown, 2000 but see Johnston, Durieux-Smith, & Bloom, 2005 for contradictory evidence). Kahn (1981) also tested this in “nonverbal, hearing, retarded” children but found the effect to be highly dependent on individuals.

Some studies also show that children use gestures for speech and language comprehension (Morford & Goldin-Meadow, 1992). Parental gestures help children map meanings on new words (Clark & Estigarribia, 2011). 18-month-olds manage to interpret gestures and words indifferently as labels for object categories, but 26-month-olds seem to have a preference for words (Namy & Waxman, 1998, see also Suanda et al., 2013).

All this put together suggests that manual gestures play a role in acquiring speech and language (Capirci & Volterra, 2008) even though it still remains unclear what this exact role is. The aim of this chapter is to better comprehend various elements of this role in the specific field of word learning. To learn a new word, one has to map both a meaning and a lexical form to a concept, which can be respectively labeled as semantic and lexical learning. “Word learning is a complex task that requires (…) to create new semantic and lexical representations, then link these new representations and integrate them with existing phonological, lexical, and semantic representations” (Kapalková, Polišenská, & Süssová, 2016, p. 59).

Gestures have been shown to support different types of learning (e.g., Kelly, Manning, & Rodak, 2008; Goldin-Meadow, 2011) and long-term memorization (e.g., Church, Ayman-Nolley, & Mahootian, 2004). More specifically, there is evidence that manual gestures could help lexical learning alone. Gestures have indeed been shown to promote the learning of words in a foreign language in children (Tellier, 2008 but see Rowe, Silverman, & Mullan, 2013) and adults (Macedonia & von Kriegstein, 2012; Kelly et al., 2014; Macedonia & Repetto, 2016). Rowe, Silverman and Mullan (2013) put forward the fact that this effect is dependent on the individual. Gogate, Bahrick and Watson (2000) observed that mothers naturally use gestures when they teach new words to their infant. Evidence also suggests that manual gestures facilitate lexical access in adults (e.g., Rauscher, Krauss, & Chen, 1996; Krauss & Hadar, 1999).

This chapter will focus on semantic and lexical learning combined, such as in the situation in which a child learns a new word from her native language. It will provide a review of the experimental evidence on the role of manual gestures in word learning. The first question it will address is whether or not the existing evidence suggests a positive role of adding manual gestures to spoken words for learning them in both typical individuals (section 3.2.) and in people with speech and language impairments of various types (section 3.3.). We will then (second question) analyze whether using manual gestures has a differential effect compared to using other additional cues (section 3.4.). The third question will examine whether there are differences between receptive and expressive learning in terms of types of effects of adding gestures (section 3.5.). We will then question whether the type of gesture has an influence (fourth question, section 3.6.). The fifth question will examine whether the effect is immediate and if it holds over time (section 3.7.). We will also examine whether producing the gesture vs. simply observing it makes a difference (sixth question, section 3.8.). Finally, the seventh question will tackle generalization of learning (section 3.9.). A discussion will then suggest several hypotheses to explain the potential positive effect of manual gestures on word learning.

2. Methodological considerations

2.1. Terminology and acronyms

In the following, expressive and receptive learning will be distinguished. Expressive (or productive) learning refers to being able to produce the learned word upon testing. Receptive (or comprehensive) learning refers to being able to comprehend the learned words upon testing. For the sake of space and clarity, the following acronyms will be used in the text: CI: Cochlear Implant; T21: Trisomy 21; SLI: Specific Language Impairment; TD: Typically Developing.

2.2. Inclusion criteria

This analysis reviews only articles written in English in order for the reader to be able to directly access their content. It explored only journal articles. Only experimental studies directly controlling training and testing material and procedures were included. We decided to exclude observational studies, even if they describe valuable data: it is indeed difficult to evaluate the size of the effects when the material used cannot be controlled and varies from one participant to the other. No further restriction was made on methodological aspects e.g., number of participants, age, language tested and type of population (typical and clinical). To be included, studies could test receptive and/or expressive learning as well as generalization. We also chose to review studies both directly evaluating the effect of gesture vs. none, those comparing different types of gestures and those comparing the use of gesture vs. other additional cues.

2.3. Exclusion criteria

Studies analyzing the role of gestures in learning words in a foreign language or learning new pseudo-words for already known words were excluded from this review in order to be more homogenous in terms of cognitive processes involved in the task performed by the participants. They are commented on in the introduction. This analysis excluded conference articles.

3. Description and analysis of selected studies

3.1. General description of the sample of studies reviewed

The final sample of studies reviewed here consists of 19 articles describing a total of 20 experimental studies relevant to the topic. Some articles describe two studies whereas some studies are analyzed in two articles from different points of views. Even though this was not a selection criterion, all the studies found dealt with children. Fourteen studies included TD children and eight included children with various disabilities (DIS) involving speech impairments: children with T21 (three studies, N=21), children with SLI/Developmental Language Disorder (three studies, N= 57), deaf and hearing-impaired children (three studies, N=38) and children with cerebral palsy (one study, N=3). Table 1 provides an overview of the characteristics of the populations involved in the studies in terms of number of participants and ages. One can note the strong variability in the number of participants included in the different studies ranging from 4 to 120 as well as in their ages ranging from a mean age

Table 1: Overview of the populations analyzed in the 20 experimental studies in terms of number of participants and age (TD = Typically Developing children; DIS = children with various disabilities involving speech impairments; mos. = months; yrs. = years; age in years: yrs.;mos.).

	Number of participants		Age of participants	
	TD	**DIS**	**TD**	**DIS**
Total	527	119		
Mean	35.1	14.9	44.1 mos. (3;8 yrs.)	82.3 mos. (6;10 yrs.)
Standard deviation	29.7	9.2	31.9 mos. (2;8 yrs.)	40.3 mos. (3;4 yrs.)
Minimum	10	4	8.45 mos.	42.3 mos. (3;6 yrs.)
Maximum	120	33	128 mos. (10;8 yrs.)	158.4 mos. (13;2 yrs.)

of 8.45 months to 13;2 years. Eleven studies dealt with English (N=401), four with Dutch (N=127), three with German (N=100) and one with Slovak (N=18). Table 2 provides details on all these studies such as number of participants, age, language, experimental design, and type of gestures tested.

3.2. Is there a general advantage of adding gestural cues for learning new words in TD children?

The aim here is to provide a first very general overview of the results of the studies concerning the efficiency of adding manual gestures to learn new words. A total of eight studies directly compared word learning with and without manual gestures (three between-subject designs and five within-subject designs) in TD children. As a whole, they tested 261 participants. Five studies (Capone & McGregor, 2005; Booth, McGregor, & Rohlfing, 2008; McGregor et al., 2009; de Nooijer et al., 2014; Lüke & Ritterfeld, 2014) involving a total of 212 children put forward a significant positive advantage of adding manual gestures during training to learn new words either expressively, receptively or both. Two studies (Bird et al., 2000; van Berkel-van Hoof et al., 2016) involving a total of 29 children found no difference between conditions: new words were learned equally well expressively and/or receptively whether they were trained alone or alongside a manual gesture. There is no clear effect of language or age on the effect of gesture on word learning (see table 2). One study (Ting, Bergeson, & Miyamoto, 2012) put forward a disadvantage of adding manual gestures: words were learned less well when trained with a manual gesture rather than alone. This specific study is however quite different from those cited above. It involved much younger children (8.5 months) and this implied using specific methods very different from those used in the others. During training, some infants were familiarized with the target words using videos in which they could see a person uttering the words while others saw the person speaking and gesturing the words. Upon testing, the infants saw videos with a speaker uttering passages including the familiarized words vs. ones with the same speaker uttering passages with words not used during training. Preference was evaluated through looking durations. The infants trained with manual gestures showed no preference for the videos with the familiarized words whereas those in the word only condition did. Even if it was important to include this study in the present review for it to be exhaustive, because of the reasons presented above, it was decided to put aside this study when tackling the following research questions. One could indeed argue that differences in the effects observed could directly result from the great methodological differences corollary to involving infants.

As a whole, the studies reviewed suggest that adding a manual gesture to the word during training improves word learning performances. A potential explanation why some studies found no effect of adding a gesture to learn new words could be that the participants were children and that the gestures used during training were produced by adults. It may be the case that, as suggested by de Nooijer and colleagues (2014), gestures produced by peer-models would be more efficient. Imitating other's actions may indeed be easier when the actions are modeled by peers of similar ages (see Schunk, 1987, mixed results however). It may also be the case that children have more facilities identifying themselves with the person modeling the action if the latter is a peer (Liuzza, Setti, & Borghi, 2012). On the other hand, this explanation is contrary to the fact that language acquisition is of course guided by interaction with adults (primarily the parents). Note however that as soon as children attend day care or school, language acquisition is also largely influenced by communicative interactions with peers.

Table 2: Summary of the information on the articles reviewed: reference (for the sake of conciseness and when there was no ambiguity, all references with more than two authors are stated as 1st author et al., year), description of the population, mean age of participants (standard deviation, range), experimental design, gesture type tested, modality during training (observation and/or imitation), type and number of words learned, existing or invented, known or not to the participants, modality during training (observation and/or imitation), number of training sessions and frequency, modality of recall (expressive and/or receptive learning), testing time: immediate and/or delayed (delay after end of training), control of gesture production during recall, summary of the results (only significant results are reported), language used in study.

Reference	**Population – no. of part. (no. of f.)**	**Age of part.: m. (sd. - rng.)**	**Experimental design (no. of gestures presented if relevant)**	**Gesture modality for training**	**Words learned: type (no.)**	**Exist. or inv.**
Booth et al., 2008	TD - 80 (39 f.) G: 16 (9 f.) GP: 16 (8 f.) GT: 16 (9 f.) GM: 16 (7 f.) BL: 16 (6 f.)	29.31 mos. (0.89 – 28–31)	**btw.:** [a] GAZE - GAZE+POI - GAZE+POI+T - GAZE+POI+T+M - BSL	obs.	n. (3)	inv.
Bird et al., 2000	T21 - 10 (? f.) TD - 10 (? f.) [b]	T21: 42.3 mos. (25–62) TD: 21.8 mos. (14–30)	**w/in.:** WD - ARB[c](4) - WD+ARB	obs. + free imit.	n. (6)	inv.
Capone & McGregor, 2005	TD - 19 (13 f.)	28.7 mos. (0.99 – 27–30)	**w/in.:** WD - WD+SHP (2) - WD+FNC (2)	obs.	n. (6)	inv.
Capone, 2007	TD[d] - 18 (12 f.)	28.72 mos. (1.02 – 27–30)				
Capone Singleton, 2012	TD - 16 (8 f.)	32.63 mos. (4.02 – 27–42)	**w/in.:** WD - WD+SHP (1) - WD+FNC (1) - WD+POI	obs.	n. (3)	inv.

Words known?	Word modality for training	No. of training ses./Frequency	Recall modality	Testing time	Gesture prod. during recall	Summary of results	Language
no	obs.	1	expr. + rec. + rec. cat. general.	imm. + deld. (3–5 d.)	no	**expr.:** GAZE~GAZE+POI~ GAZE+POI+T~ GAZE+POI+T+M~BSL - imm. > deld. **rec. & rec. general.:** GAZE+POI, GAZE+POI+T GAZE+POI+T+M > BSL	English
no	obs. + free imit.	3 / ?	expr. + rec.	imm.	no	**expr.:** TD > T21 - WD~ARB~WD+ARB **rec.:** T21: WD+ARB>WD ~ARB - TD: none	English
no	obs.	3 / daily	expr. + rec.	imm. + deld. (~ 9.5 d.)	yes (Capone, 2007)	**expr.:** uncued resp.: WD+SHP>WD~WD+FNC - cued resp.: WD+SHP~ WD+FNC>WD **rec.:** WD+SHP>WD+FNC~ WD~chance	English
no	obs.	3 / ~ every 2 d.	expr. + cat. general. (expr. + rec.)	deld. (~ 4.1 d.)	no	**All tests:** WD+SHP>WD+POI~ WD+FNC	English

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Table 2: Continued

Reference	Population – no. of part. (no. of f.)	Age of part.: m. (sd. - rng.)	Experimental design (no. of gestures presented if relevant)	Gesture modality for training	Words learned: type (no.)	Exist. or inv.
de Nooijer et al., 2014	TD - 53 (31 f.)	8.6 yrs. (0.6)	**w/in.:** DEF - DEF+PANT[e](6) - DEF+PANT+IMIT (6) - DEF+ACT	obs. and/ or imit.	v.[f] (24)	exist.
Giezen et al., 2013 (study 2)	CI - 8 (2 f.) prelingually deaf	6;11 yrs. (9 mos. - 5;9–8;1)	**w/in.:** WD - ARB (8) - SSS	obs.	n. (8)	inv.
Kapalková et al., 2016	TD - 18 (12 f.)	2 yrs.(24–34 mos.)	**btw.:** WD+ICO[g] (10) - WD+PIC	obs. + imit.	? (10)	inv.
Kohl et al., 1979	H - 4 (? f.)3 CP, 1 T21	13.2 yrs. (11.1–16.1)	**w/in.:** WD - PartSgn - CompSgn	obs.	n. (18) + v. (6) + prep. (6)	exist.
Lüke & Ritterfeld, 2014 (study 1)	TD - 20 (5 f.)	4;9 yrs. (3;4–5;11)	**w/in.:** WD+ICO[h] (3) - WD+ARB (3) - WD	obs.	n. (9)	inv.
Lüke & Ritterfeld, 2014 (study 2)	SLI[i] - 20 (7 f.) WD+ICO: 10 (5 f., 4 bil.) WD: 10 (2 f., 5 bil.)	4;7 yrs. (3;4–5;7)	**btw.:** WD+ICO (9) - WD	obs.	n. (9)	inv.
McGregor et al., 2009	TD[j] - 40 (21 f.) WD: 13 (7 f.) WD+G: 12 (8 f.)WD+P: 15 (5 f.)	1;8–2;0 yrs. WD: 20.68 mos. (0.95) WD+G: 21 mos. (1.54) WD+P: 21.26 mos. (1.38)	**btw.:** WD - WD+ICO[k] (1) - WD+PHO	obs.	Under	exist.

Words known?	Word modality for training	No. of training ses./Frequency	Recall modality	Testing time	Gesture prod. during recall	Summary of results	Language
no	obs.	2 / daily	def. recall + rec.	imm.	no	**def. recall:** DEF+PANT>DEF, DEF+ACT for loc. v. (vs. abs. & obj.) **rec.:** none	Dutch
no	obs.	1	rec.	imm.	no	WD~ARB~SSS	Dutch
no	obs. + imit.	15 / 4 times a wk.	expr.	deld. (T1: 1 d.; T2: 2 wk.; T3: 6 wk.)	no	WD+ICO>WD+PIC T1>T3 - T1~T2 - T2~T3	Slovak
no	obs.	15 / daily (Mond. - Sat.)	expr. + rec.	imm.	yes	**expr.:** for 1 part. only PartSgn, CompSgn > WD **rec.:** CompSgn~PartSgn>WD	English
no	obs.	1	expr. + rec.	imm.	no	**expr.:** none, no correct labelings **rec.:** WD+ICO~WD+ARB> WD	German
no	obs.	3 / weekly	expr. + rec.	imm. / deld. (1 wk.)	no	**imm.:** expr. & rec.: none **deld.:** T1 & t2: expr.: WD+ICO>WD rec.: none	German
no except 4 part.	obs.	1	rec. + general.	imm. / deld. (2–3 d.)	no	**rec.:** WD+ICO~WD>WD+PHO - imm.~deld.>pre-test **rec. general.:** WD+ICO~WD>WD+PHO - deld.>imm.~pre-test **WD+ICO:** deld.>pre-test, deld.~imm., imm.~pre-test	English

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Table 2: Continued

Reference	Population – no. of part. (no. of f.)	Age of part.: m. (sd. - rng.)	Experimental design (no. of gestures presented if relevant)	Gesture modality for training	Words learned: type (no.)	Exist. or inv.
Mollink et al., 2008	HI - 14 (10 f.) All wore hearing aids	5;11 yrs.(13 mos. - 4;4–8;3)	**w/in.:** CTL - WD - WD+SGN[l] (16) - WD+CLR[m]	obs.	n. (64)	exist.
Mumford & Kita, 2014	TD - 120 (57 f.) WD+MG: 36 WD+ESG: 32 WD: 33	41.48 mos. (3.13 – 36–47)	**btw.:** WD - WD+MG (5) - W+ESG (5)	obs.	v. (5)	inv.
O'Neill, Topolovec, & Stern-Cavalcante, 2002 (expe. 1)	TD - 40 (22 f.) DES: 20 (12 f.) POI: 20 (10 f.)	DES: 33.9 mos.(0.98, 32–35) POI: 34.8 mos. (1.11, 33–36)	**btw.:** WD+ICO[n] (5) - WD+POI	obs.	adj. (5)	exist.
O'Neill, Topolovec, & Stern-Cavalcante, 2002 (expe. 2)	TD - 32 (16 f.) DES: 16 (8 f.) POI: 16 (8 f.)	DES: 39.8 mos.(1.76, 37–43) POI: 40.6 mos. (1.75, 37–43)	**btw.:** WD+ICO[o] (4) - WD+POI		adj.[p] (4)	
Romski & Ruder, 1984	T21 - 10 (? f.)	5:7 yrs. (14.94 mos., 3:11–7:10)	**w/in.:** CTL[q] - WD - WD+SGN[r] (4)	obs. + enactment of actions on obj.	n. (12) + v.[s] (12)	exist.
Ting et al., 2012	TD - 20 (? f.) WD+SGN: 10 WD: 10	WD+SGN: 8.5 mos. (1, 7–9.5) WD: 8.4 mos. (0.93, 7.1–9.5)	**btw.:** WD - WD+SGN[u] (4)	obs.	n. (4)	exist.

Words known?	Word modality for training	No. of training ses./Frequency	Recall modality	Testing time	Gesture prod. during recall	Summary of results	Language
no	obs. + imit.	3 / weekly	expr.	deld. (T1: 1 wk; T2: 5 wk.)	no	**condition:** WD+SGN> WD+CLR~WD>CTL **test time:** T1>T2 **iconicity:** T1: strong~weak - T2: strong>weak	Dutch
no	obs.	1	rec. general.	imm.	no	WD+MG>WD~WD+ESG	English
var.	obs.	1	rec. general.	imm.	yes	Tendency towards WD+ICO>WD+POI	English
no						WD+ICO>WD+POI	
no[t]	obs.	m.=23.1 (rng.=10–48) / daily (weekdays)	expr. + rec. + rec. general.	deld. (?)	yes	**expr.:** few resp. - WD~WD+SGN **rec.:** not sig. but ad. for 5 part. dis. for 2 part. none for 3 part. **expr. general.:** WD>WD+SGN **rec. general.:** WD+SGN>WD - rec.>expr.	English
no	obs.	1	rec.	imm.	no	**looking time:** WD+SGN: trained~untrained WD: trained>untrained	English

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Table 2: Continued

Reference	Population – no. of part. (no. of f.)	Age of part.: m. (sd. - rng.)	Experimental design (no. of gestures presented if relevant)	Gesture modality for training	Words learned: type (no.)	Exist. or inv.
van Berkel-van Hoof et al., 2016	52 (25 f.)HI[v] - 16 (? f.) SLI[w] - 17 (? f.)TD - 19 (? f.)	10;8 yrs. (8.47 mos., 9–11)	**w/in.:** WD - WD+ICO[x] (10)	obs. + imit.	n. (20)	inv.
Vogt & Kauschke, 2017a	SLI - 20 (10 f.) TD AM - 20 (10 f.)TD LM - 20 (11 f.)No exposition to gesture or sign	SLI: 4;6 yrs. (0;7) TD AM: 4;5 yrs. (0;3)TD LM: 3;3 yrs. (0;16)	**w/in.:** WD+ICO (var.) - WD+ATT[y] (1)	obs.	n. (var.)[z] + v. (var.)[aa]	exist.
Vogt & Kauschke, 2017b						

Abbreviations (in alphabetical order): **ad.:** advantage – **adj.:** adjective – **beg.:** beginning – **bil.:** bilingual – **btw.:** between-subject design – **cat.:** category – **d.:** day – **def.:** definition – **deld.:** delayed – **dis.:** disadvantage – **exist.:** existing – **expe.:** experiment – **expr.:** expression – **f.:** female – **general.:** generalization – **imm.:** immediate – **imit.:** imitation – **inv.:** invented – **m.:** mean – **mo.:** month – **mos.:** months – **n.:** noun – **no.:** number – **obj.:** object – **obs.:** observation – **part.:** participant – **prep.:** preposition – **prod.:** production – **rec.:** reception – **rng.:** range – **sd.:** standard deviation – **ses.:** session – **sig.:** significant – **v.:** verb – **var.:** variable – **w/in.:** within-subject design – **wk.:** week – **yr.:** year – **yrs.:** years.
Acronyms (in alphabetical order): **AM:** Age-matched group (individually matched in chronological age (+/- 9 mos.) and gender) – **CI:** Cochlear Implant (prelingually deaf) – **CP:** Cerebral Palsy – **HI:** Hearing Impaired – **T21:** Trisomy 21 – **H:** Handicapped – **LM:** Language-matched group (individually matched on grammar comprehension, receptive and expressive vocabularies (nouns and verbs), word definition and nonword repetition (scores +/- 1/2 sd)) – **SLI:** Specific Language Impairment – **SLN:** Sign language of the Netherlands – **TD:** Typically Developing.

Words known?	Word modality for training	No. of training ses./Frequency	Recall modality	Testing time	Gesture prod. during recall	Summary of results	Language
no	obs. + imit.	3 / w/in. 1 wk.	rec.	Beg. of ses. 2 (T1) and 3 (T2) + 1 ses. within same wk. (T3)	no	**HI:** WD+ICO>WD - T1<T2<T3 - ad. gets larger over time **SLI:** WD+ICO~WD - T1<T2<T3 **TD:** same as SLI	Dutch
no	obs.	3 / every 2–3 d.	expr. + rec.	imm. after 1st training ses. (T1)/ deld. (T2, 2–3 d.)	no	**expr.:** WD+ICO>WD+ATT - T2>T1>pre-test T1: v.: WD+ICO>WD+ATT, n.: WD+ICO~WD+ATT T2: v.: WD+ICO~WD+ATT, n.: WD+ICO>WD+ATT **rec.:** WD+ICO>WD+ATT -T2>T1>pre-test	German
			def. prod.	deld. (2–3 d.)		**General tendency**: WD+ICO>WD+ATT - LM<SLI~AM	

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Table 2: Continued

Experimental conditions: ACT: action enactment (part. asked to create a ges.) – **ARB:** arbitrary sign (no iconic resemblance with referent) – **ATT:** attention-directing gesture – **BSL:** baseline – **CompSgn:** complete signing (all words are signed), signs from Signed English Dictionary, 1 sign for each word – **CTL:** control (no training: only pre-test and post-test) – **DEF:** verbal definition – **ESG:** end-state gesture (depicts shape or lines formed by action) – **FNC:** function gesture (dynamic symbol) – **ICO:** iconic gesture – **IMIT:** gesture imitation – **MG:** manner gesture (depicts action of the hand) – **PANT:** pantomime – **PartSgn:** partial signing (signing of keywords only) – **PHO:** photo – **PIC:** picture – **POI:** pointing at target – **SGN:** sign – **SHP:** shape gesture (static symbol) – **SSS:** Sign Supported Speech – **WD:** word

[a] GAZE: Experimenter gazes at target – T: Experimenter additionally extends arm till touches object – M: Experimenter additionally pushes object across the table – BSL: Experimenter looks at table midway from target and foil

[b] Group matching: mental age - T21 trained in manual signs - TD no

[c] Signs produced with both hands symmetrically

[d] Subgroup of Capone & McGregor (2005)

[e] Gesture observation only

[f] Verbs of 3 types: locomotion (loc.), object-manipulation (obj.), abstract (abs.)

[g] Gestures based on Slovak Sign Language

[h] Iconics constructed or adopted from German Sign Language (visible feature of characters' head or neck)

[i] Group matching: age, sex, bilingualism

[j] Group matching: chronological age, total number of words, number of spatial terms

[k] Experimenter holds right hand over left and moves right hand under the left

[l] Signs from the Sign Language of the Netherlands – 2 sub-conditions: strong and weak iconicity

[m] Experimenter names a color in addition to naming the picture

[n] Demonstrating property described by adjective, performed on toy

[o] Demonstrating property described by adjective, performed on toy

[p] Adjectives describing tactile properties applied to animal names familiar to the participants

[q] Control for natural acquisition of the trained words (only pretest and postest)

[r] Signs from Signing Exact English (Gustason, Pfetzing, & Zawolkow, 1975)

[s] Transitive verb, representing object manipulation

[t] Individualized selection for each participant to select unknown words

[u] Signs from Signing Exact English (Gustason, Pfetzing, & Zawolkow, 1975) – 2 signs out of 4: iconic; 2 other arbitrary

[v] Hearing aids of different types – exposed or users of the SLN

[w] Some exposed to SSS

[x] Gestures invented accordingly to SLN formational principles and depicting "a defining feature" of the character

[y] Attention-directing gesture: raised forefinger in front of upper body

[z] Shape of animal – no. of nouns taught: TD AM: 6; SLI & TD LM: 4

[aa] Manner and/or path of movement – no. of verbs taught: TD AM: 6; SLI & TD LM: 4

3.3. Is there a general advantage of adding gestural cues for learning new words in children with speech and language deficits of various types?

A total of seven studies directly compared word learning with and without manual gestures (one between-subject design and six within-subject designs) in children with speech and language difficulties. They tested a total of 99 children. Giezen, Baker and Escudero (2013; N=8) found no effect of adding a manual gesture for word learning in children with CI. Van Berkel-van Hoof and colleagues (2016; N=17) found the same result for children with SLI. All other studies found an advantage of using manual gestures for learning new words, whether it be expressively or receptively or both, in a total of 74 participants (children with T21: Kohl, Karlan, & Heal, 1979; Bird et al., 2000; Romski & Ruder, 1984 – children with SLI: Lüke & Ritterfeld, 2014 – children with hearing impairments: Mollink, Hermans, & Knoors, 2008; van Berkel-van Hoof et al., 2016 – children with cerebral palsy: Kohl, Karlan, & Heal, 1979). Among the latter studies, Bird and colleagues (2000) and van Berkel-van Hoof and colleagues (2016) also included a group of TD children for which they found no effect of adding manual gestures to the learning of new words. The lack of a positive effect in Giezen, Baker and Escudero (2013; children with CI) could be explained by the fact that they used only one training session and only immediate and no delayed testing. The number of taught words was also very important (64) which could result in a floor effect. The authors interestingly put forward that, even if there was no positive effect, there was no negative effect either. Using manual gestures thus did not interfere with word learning.

The results of the reviewed studies therefore suggest that manual gestures could help children with speech and language difficulties learn new words, maybe even more so than for TD children. Van Berkel-van Hoof and colleagues (2016) actually found a positive effect of gestures for word learning only for hearing impaired children (vs. TD children and SLI children). They hypothesize that "Because these children are bimodal bilinguals, they process augmentative signs through the phonological loop as they do speech" (p. 346). Gestures may be more effective to help learn new words when the participants are used to using and/or seeing gestures.

Bird and colleagues (2000) indeed found a positive effect of signs for word learning in children with T21 familiar with signing but not in TD children. Van Berkel-van Hoof and colleagues (2016) also found a positive effect of iconic gestures for children with hearing impairments familiar with sign language whereas they found no such effect in children with SLI and TD children. Note however that this hypothesis is not backed by the fact that a number of other studies did find positive effects of gestures for word learning in TD children who had never been exposed to signs. There may be interferences with other factors such as age and duration of training, but these are difficult to analyze because of the variability in methodologies used and populations tested. A crucial point is that none of the studies found a negative effect of adding manual gestures for word learning: either there was no effect or a positive one.

3.4. Are manual gestures more (or less) efficient than other additional cues for word learning?

It could be the case that providing any additional cue, whether it be a manual gesture or something else, could improve word learning. This section examines in more detail the studies comparing the effect of using manual gestures to that of using other additional cues. Booth, McGregor and Rohlfing (2008) compared several conditions: 1. using pointing to the object to learn its label; 2. additionally touching it; 3. additionally moving it across the table (in TD children). There was no advantage of the two latter conditions compared to the former which all yielded similar positive effects for receptive word learning compared to a word alone condition. This suggests that the advantage solely emerged from using a pointing gesture since adding other cues did not further improve the effect.

Kapalková, Polišenská and Süssová (2016) analyzed expressive word learning in two groups of TD participants: one of them learned the words alongside manual gestures and the other with pictures. Even though participants managed to learn the new words in both groups, performances were significantly better in the gesture group.

McGregor and colleagues (2009) compared the learning of the preposition ‘under’ in three groups of TD children: one with the word only, one with an additional manual gesture, and one with a photograph. The results show that performance improved from pre-test to immediate testing after training to a similar extent in all groups. A further analysis, however, showed a manual gesture advantage when comparing performance at pre-test and delayed post-test. This suggests that manual gestures promote learning more than photographs, not immediately after training, but after a two- to three-day delay. Manual gestures would thus be more efficient for maintaining word learning over time.

Mollink, Hermans and Knoors (2008) compared adding a sign to the spoken word during training to adding a color (labeled verbally by the experimenter during learning) to providing the word alone in children with hearing impairments. They found that receptive learning performances were better for the word + sign condition than for the two other conditions and not different for the two other conditions. This suggests that adding a color does not help promote word learning more than learning the word alone whereas adding a gesture does.

The results of the above four studies suggest that adding a manual gesture to the word during training is not equivalent to adding any other cue. It appears that the gesture plays a different role than other additional cues such as pictures.

3.5. Is there a differential effect of gesture on expressive vs. receptive learning? Interaction with number of training sessions

As stated in section 2, two types of learning can be distinguished: expressive and receptive learning. The aim of this section is to differentially examine the effect of adding manual gestures to the learning of new words for expressive and receptive learning.

Out of the seven studies cited to address the question in section 3.2. and directly comparing the use of gesture vs. none for word learning in TD children, four tested receptive learning only (McGregor et al., 2009; Ting, Bergeson, & Miyamoto, 2012; de Nooijer et al., 2014; van Berkel-van Hoof et al., 2016) and four evaluated receptive and expressive learning (Bird et al., 2000; Capone & McGregor, 2005; Booth, McGregor, & Rohlfing, 2008; Lüke & Ritterfeld, 2014).

Concerning receptive learning, four studies (Capone & McGregor, 2005; Booth, McGregor, & Rohlfing, 2008; McGregor et al., 2009; Lüke

& Ritterfeld, 2014) put forward an advantage of using gestures (vs. none) to learn new words, whereas the three others (Bird et al., 2000; de Nooijer et al., 2014; van Berkel-van Hoof et al., 2016) found no effect. The number of training sessions does not seem to explain the fact that some studies found no effect: two of the studies finding no effect used three training sessions and one of them used two, whereas three studies finding a positive effect of using manual gestures used only one training session and another study only three sessions. Another hypothesis to explain differences in the results could be the number of words learned. de Nooijer and colleagues (2014) taught 24 words to the participants and van-Berkel-van Hoof and colleagues (2016) 20 and found no effect, whereas all other studies finding a positive effect of adding manual gestures to learn new words taught between one and nine words.

Recall that all the studies testing expressive learning also analyzed receptive learning. Only one study (Bird et al., 2000) found no effect of gestures on both expressive and receptive learning. Booth, McGregor and Rohlfing (2008) as well as Lüke and Ritterfeld (2014) found that whichever condition (gesture or none), the participants did not manage to learn the new words expressively, even though they did receptively with an advantage for the gesture condition. As stated by Booth, McGregor and Rohlfing (2008), this may be due to insufficient training (only one session in both studies). Expressive learning would thus require more training than receptive learning. This hypothesis is corroborated by the results of Capone and McGregor (2005) who found a positive effect of iconic gestures underlying shape (vs. iconic gestures depicting function and no gesture) for learning new words after three training sessions. Note that when the participants did not manage to provide an expressive response, the experimenter provided a gestural cue. For these cued responses, the authors found a positive effect of both types of iconic gestures over no gesture. In the no gesture condition, the participants did not manage to provide any expressive responses even though they managed to learn some words receptively just as in Booth, McGregor, & Rohlfing (2008) and Lüke & Ritterfeld (2014). Capone Singleton (2012) obtained similar results comparing shape gestures, function gestures and pointing gestures: shape gestures showed an advantage over function and pointing gestures for expressive word learning after three training sessions. Overall, these observations corroborate the fact that receptive learning is faster than expressive learning and that adding gestures can promote faster expressive learning even though such learning still takes longer than receptive learning. Note however that Vogt and Kauscke (2017a) found an advantage of iconic gestures over attention-directing gestures even at the end of the first training session for expressive learning. Booth, McGregor and Rohlfing (2008) also suggest that the lack of a positive effect of gestures on expressive learning may be due to the fact that the participants were not asked to produce the words during training (also the case in Lüke & Ritterfeld, 2014 and Capone & McGregor, 2005). All these arguments are further corroborated by the study by Kapalková, Polišenská and Süssová (2016) who found positive effects of using iconic manual gestures (vs. picture support) on expressive word learning after 15 sessions in a paradigm in which participants produced the words during training.

Out of the seven studies addressing the effect of adding a manual gesture on learning new words in children with speech and language difficulties (section 3.3.) and directly comparing the use of gesture vs. none, two tested receptive learning only, one expressive learning only and four both receptive and expressive learning. All studies, except Giezen, Baker, & Escudero (2013) and Lüke & Ritterfeld (2014), found a positive effect of adding manual gestures to the learning of new words receptively for at least one group of children with speech and language impairments. Note however that the effect was not significant in Romski and Ruder (1984): it was positive for only five out of 10 children with T21. Van Berkell-van Hoof and colleagues (2016) found a gestural advantage for receptive learning for children with hearing impairments but not for those with SLI.

Bird and colleagues (2000) found no effect of adding manual gestures to the learning of new words expressively in children with T21 even though they did for receptive learning. Lüke and Ritterfeld (2014) and Mollink, Hermans and Knoors (2008), on the other hand, report a positive effect respectively in children with SLI and hearing impairments. The effect is also positive in Kohl, Karlan, and Heal (1979) for children with T21 or cerebral palsy but it does not reach significance. Results from Romski and Ruder (1984) are unclear. It appears that a positive effect for expressive learning was obtained more often in children with disabilities compared to TD children (see above). To build on the discussion above, it is also the case that the studies dealing with children with disabilities often included more training sessions than those dealing with TD children.

In a nutshell, the effect of manual gesture on receptive learning appears to be influenced by the number of words taught: when too many words are taught no advantage for gestures appears. Concerning expressive learning, some studies find no effect of gesture, but this is mainly due to the fact that the children did not manage to learn the words expressively whichever the condition mainly because of insufficient training (floor effect). With more training, children managed to learn new words expressively with an advantage when manual gestures were present during training (though see Vogt & Kauscke, 2017a, for an advantage of gesture on expressive word learning after only one training session). It seems that the positive effect of manual gestures on expressive word learning is greater for children with speech and language impairments though the studies involving such participants generally included more training sessions than those with TD children.

3.6. Does gesture type matter? Does iconicity matter?

The aim of this section is to analyze whether the experimental evidence puts forward a specific advantage of adding different types of manual gestures to the learning of new words. Specifically, one could hypothesize that if the gesture puts forward an iconic resemblance with the referent it could be more beneficial for learning the new word labeling the referent: "if a sign is more iconic than the spoken word, its form conveys information about a word's meaning and may thus assist a child in mapping new words to meanings" (Bird et al., 2000, p. 260).

Lüke and Ritterfeld (2014) found that both iconic and arbitrary gestures were equally beneficial to word learning in TD children aged 4;9 years. This could appear as contrary to the results of Namy and Waxman (1998) who compared the ability of children from 18 to 26 months to learn either word or arbitrary gestural labels. They found that 18-month-olds learned word or gestural labels indifferently whereas 26-month-olds learned word labels more easily and needed extra training to learn gestural labels. Bird and colleagues (2000) also found that 21.8-month-olds were not able to expressively learn arbitrary gestural signs alone as labels. Marentette and Nicoladis (2011) found that children aged 40 to 60 months could learn iconic gesture labels for objects but not arbitrary gesture labels. This difference in findings could suggest that, even if children have difficulties learning only an arbitrary gestural label (without a word) for an object, the arbitrary gesture could however help them learn a corresponding and simultaneously presented word (at least receptively). Lüke and Ritterfeld (2014) hypothesize that "arbitrary gestures may have enhanced the interest of the child in the presented words in contrast to words introduced without gestures". This finding is however contradictory to that of Bird and colleagues (2000) who found no difference between a word only and a word + arbitrary sign condition on expressive and receptive word learning (mean age = 21.8 months). This difference in findings could be due to the age of the participants: the ones in the Bird et al. (2000) study may have been too young to manage to learn arbitrary signs even though Namy and Waxman (1998) found that 18-month-olds can learn words and arbitrary gestural labels. This hypothesis is backed by the fact that Bird and colleagues (2000) did find a beneficial effect of arbitrary signs for receptive learning of new words in older children with T21 (mean age = 42.3 months). Note however that the participants with T21 were trained in using signs prior to the study whereas TD children were not. Giezen, Baker and Escudero (2013) found no benefit in adding arbitrary signs to learn new words in 6;11-year-old children with CI. The scores were however close to 100 % and the absence of a gesture benefit could be due to a ceiling effect.

Another surprising observation, taking into account the results of Marentette and Nicoladis (2011), is that Lüke and Ritterfeld (2014) found no advantage of iconic gestures over arbitrary ones. This could be due to a ceiling effect for iconic gestures (as suggested by the authors themselves). Vogt and Kauschke (2017a) ran an interesting follow-up experiment to their main study comparing iconic and attention-directing gestures. It compared the use of iconic gestures versus arbitrary ones. Even though sample size was small (18 TD children) and impeded reaching statistical significance (according to the authors themselves), the results suggest that both expressive and receptive performances were higher for the iconic than the arbitrary gesture condition.

Mollink, Hermans and Knoors (2008) found a positive effect of adding signs to words for receptive word learning in hearing impaired children.

They analyzed this effect as a function of sign iconicity. Even though the effect was the same for signs with strong iconicity than for those with weak iconicity one week after training, the results after five weeks show that learning was better for strongly iconic signs. The interesting thing is that at five weeks, the performance decreased compared to one week only for weakly iconic signs but remained the same for strongly iconic signs suggesting that iconicity helped longer memory retention. This finding is corroborated by that of van Berkel-van Hoof and colleagues (2016) who found a positive effect of adding iconic signs for receptive word learning in hearing impaired children. Note however that they did not find a beneficial effect of iconic gestures over none in 10;8-year-old TD children and children with SLI. Lüke and Ritterfeld (2014) did find a beneficial effect of iconic gestures over none in 4;7-year-old children with SLI.

Capone and McGregor (2005) and Capone Singleton (2012) compared the effect of using iconic gestures underlying shape to ones underlying function. They found that shape gestures were more efficient in promoting expressive and receptive word learning than function gestures. This suggests that type of iconicity could be as important as iconicity itself. In both studies the shape gestures were static symbols and the function gestures were dynamic symbols. Even if performances on words trained with a function gesture were generally not better than those for words trained with no gesture, the authors put forward an interesting finding. In expressive learning testing, when the participants did not manage to produce the word, the experimenter provided the gestural cue. In these cases, function gestures functioned as good as shape gestures to help the children produce the new words upon testing, suggesting that function gestures may have a beneficial effect even though they are not as effective as shape gestures. Capone Singleton (2012) speaks of a shape bias already put forward by other researchers (Kemler Nelson et al., 2000; Smith et al., 2002). Mumford and Kita (2014) also compared different types of iconic gestures for learning new verbs receptively: ones underlying the manner of an action (dynamic) and the other its resulting end state (shape, static). Contrary to the above-mentioned studies, the authors found a beneficial effect over word only training solely for the dynamic manner gestures and not for the static end state gestures. This may be due to a difference in the ages of the participants: the participants were aged 41.48 months on average whereas those in the Capone studies were aged around 28 months. Actually, it appears that the shape bias mentioned above would wear off with age (Imai, Gentner, & Uchida, 1994). Also note that in the Mumford & Kita (2014) study, the children learned verbs whereas they learned nouns in the Capone studies. Vogt and Kauscke (2017a) compared iconic gestures underlying path and/or manner to ones underlying shape. They found a larger advantage for path-manner than shape gestures for immediate learning of verbs but similar effects for both gesture types for immediate learning of nouns. On the other hand, after a two- to three-day delay from the end of training, they found a larger advantage for shape than path-manner gestures for nouns but similar effects for both gesture types for verbs. This result helps understand the differences between the Mumford & Kita study and the Capone studies.

Vogt and Kauscke (2017a) found an advantage of iconic gestures over attention-directing gestures (raised forefinger in front of upper body) even at the end of the first training session. The authors conclude that: "it is the iconicity of the gestures (that is the resemblance to the referent), rather than the item-specific encoding of both auditory and visual information to a lexical form, that helps learning" (p. 22). O'Neill, Topolovec and Stern-Cavalcante (2002) analyzed the generalization of the use of newly learned adjectives to qualify other objects than those used during training with a similar distinctive quality referred to with the adjective. For example, during training, the children were presented with a 'lumpy cat' and taught the adjective 'lumpy'. Upon testing they were presented with a 'lumpy turtle' and a 'smooth turtle' and asked to designate the 'lumpy' one. During the learning phase, some adjectives were learned with a descriptive gesture and others with a pointing gesture. In a first experiment, they found no difference between the two conditions except for the adjectives describing non-visual properties of objects (descriptive gesture advantage) and concluded that: "gesture may play a more important role in the learning of less visually detectable properties" (p. 255). In a second experiment, using lower frequency adjectives describing only non-visible properties, they found that descriptive gestures were more efficient in promoting learning than pointing gestures. An interesting finding is a higher frequency of mention of nontarget properties (resp. less expression of uncertainty during testing) by the participants in the pointing than in the descriptive gesture condition, but only in experiment 1. Capone Singleton (2012) compared iconic gestures underlying shape to pointing. She found that shape gestures were more efficient in promoting expressive and receptive word learning than pointing. Booth, McGregor and Rohlfing (2008) however found that the use of pointing by the experimenter during training yielded better receptive learning than not using any gesture. It may therefore be the case that attention-directing gestures are also beneficial for word learning, but less than iconic gestures.

Overall, the studies reviewed here suggest that different types of manual gestures can have differential effects. Pointing gestures appear to be helpful for word learning compared to no gesture even though there is some evidence that gestures having an iconic resemblance with the referent would be more effective. "the use of descriptive gestures during the teaching of novel adjective terms appears (…) to have helped children to isolate the particular property intended by the speaker in a manner not possible when point gestures were used instead" (O'Neill, Topolovec, & Stern-Cavalcante, 2002).

Results of the studies comparing arbitrary and iconic signs do not all agree but do suggest in general that iconics are more beneficial. Several studies also put forward differences between iconic gestures with a bias of shape over function for nouns and path-manner over shape gestures for verbs. Capone and McGregor (2005) suggest that the role of gestures is to draw "attention to an important aspect of the word learning problem (shape, function or both), thereby reinforcing salient semantic content of the spoken language" (p. 1478). As suggested by Vogt and Kauschke (2017a), iconic gestures may facilitate the association with the lexical form. Type of iconic gesture could interact with type of word learned (e.g., nouns vs. verbs) and also the word itself. For example, one could hypothesize that some words are better represented by static shape iconic gestures (e.g., hands shaped as a round to illustrate the word 'ball') and others by dynamic function gestures (e.g., fingers miming cutting to illustrate the word 'scissors').

3.7. Does testing time matter?

Some of the studies reviewed tested the participants immediately after training, others after various delays and others at both times. Immediate testing tackles fast mapping, the initial stage of word learning "in which a first connection of a word and referent is retained (Carey, 2010; Carey & Bartlett, 1978)" (Lüke & Ritterfeld, 2014, pp. 203–204). Delayed testing examines slow mapping, the retention of meaning and label association in memory when the "child forms a robust and more sophisticated lexical representation of the word (Carey, 2010; Horst, Parsons, & Byron, 2011)" (Lüke & Ritterfeld, 2014, p. 204). It is possible that a gestural effect could appear both at the stages of fast and slow mapping or only after some time as observed in other learning tasks (e.g., Cook, Mitchell, & Goldin-Meadow, 2008; Cherdieu et al., 2017).

A total of five studies (iconic gestures: Capone & McGregor, 2005; Lüke & Ritterfeld, 2014; Mumford & Kita, 2014; Vogt & Kauschke, 2017a; pointing: Booth, McGregor, & Rohlfing, 2008) put forward a beneficial effect of using iconic gestures to fast map new words receptively but not expressively (except Vogt & Kauschke, 2017a) in TD children (no gestural benefit: Bird et al., 2000).

Lüke and Ritterfeld (2014) found similar results for children with SLI (positive effect of gestures on receptive word learning). Bird and colleagues (2000) found the same for children with T21 and Kohl, Karlan and Heal (1979) for one child with T21 and three children with cerebral palsy. Giezen, Baker and Escudero (2013) however found no positive effect of using gestures during training for immediate receptive word learning in children with CI. Note that they used arbitrary signs whereas Lüke and Ritterfeld (2014) used iconic gestures (see section 3.6. for discussion on this topic). Bird and colleagues (2000) also used arbitrary signs but the children were exposed five times more to each label than those in the Giezen, Baker, & Escudero (2013) study. Finally, note that the testing scores in the Giezen, Baker, & Escudero (2013) study were relatively high (above 80 % correct responses) suggesting a possible ceiling effect.

Booth, McGregor and Rohlfing (2008) found a positive effect of pointing gestures on receptive word learning in TD children both immediately and after a three-to five-day delay. The same was obtained for iconic gestures by Capone and McGregor (2005; 11.5-day delay). Kapalková, Polišenská and Süssová (2016) found an effect of testing delay on general expressive word learning, all conditions (picture vs. iconic gesture support) put together with no interaction. Note however that all testing sessions were delayed (one day after end of training vs. two weeks and six weeks), performances being better after one day than after two or six weeks. McGregor and colleagues (2009) however find a larger effect of gesture (over speech only) on the receptive acquisition of the preposition ‘under’ only after two to three days and not at immediate testing and only for generalization (not for trained pairs of objects). Note however that in all conditions including the speech only condition, the experimenter modeled the ‘under’ relationship on objects during training. Even though this is not a manual gesture per se, it may act as a gesture, which would explain the results. The authors also analyzed the correlation between short-term and long-term performances and found, only for the gesture group, that “children who demonstrate modest gains on the immediate post-test build on those gains for a more impressive performance at delayed post-test” (p. 819) and this only for unlearned combinations: “The gesture advantage was revealed by the children’s ability to follow under instructions given the untrained generalization items” (p. 820). Lüke and Ritterfeld (2014) found the same result in children with SLI, the positive effect of gesture only emerging for expressive (and not receptive) learning after a one-week delay. Vogt and Kauschke (2017a) found no effect of condition x testing time on performance in expressive and receptive word learning in TD and SLI children but this study did not include a ‘no gesture’ condition, it only compared the use of iconic and attention-directing gestures.

Van Berkel-van Hoof and colleagues (2016) only used delayed testing at several time points and found no advantage for iconic gestures over speech in all cases in TD and SLI children even though word learning performance improved over time (three testing time points). This improvement is probably due to the fact that there was extra training between testing times. Note that they did, however, find a positive effect of using gestures during training in hearing impaired children and that this advantage increased in magnitude over time. Mollink, Hermans and Knoors (2008) also found positive effects of adding signs to words for receptive word learning in hearing impaired children one week and five weeks after the end of training (no fast mapping testing). In contrast to van Berkel-van Hoof and colleagues (2016), they found that instead of increasing, performance decreased with time. This discrepancy however probably stems from the fact that they tested children after one and five weeks whereas van Berkel-van Hoof and colleagues (2016) tested children only one or two days after the end of training.

To summarize, in general, upon immediate testing, there is a gestural effect essentially for receptive learning in TD children as well as in children with speech and language impairments. This effect generally holds for delayed testing. Some studies however find no immediate advantage but do find a gestural advantage upon delayed testing, especially for expressive learning. Note that Brown and colleagues (2012) as well as McGregor (2014) found that performances in recall of newly learned words were better after 12 or 24 hours than immediately.

3.8. Is observing the gesture during training enough or does producing the gesture work better?

This section examines whether simply observing a gesture promotes word learning or if also producing it during the training phase could be more helpful. Some studies have indeed shown that imitating the gesture during training improves the beneficial effect of manual gestures for learning words in a foreign language (e.g., Macedonia, Bergmann, & Roithmayr, 2014).

A total of five studies (Capone & McGregor, 2005; Booth, McGregor, & Rohlfing, 2008; McGregor et al., 2009; Lüke & Ritterfeld, 2014; Mumford & Kita, 2014) found a positive effect of adding a gesture during training to learn new words through observation of gesture in TD children. The same observation was made by Kohl, Karlan and Heal (1979) for one child with T21 and three with cerebral palsy, by Lüke and Ritterfeld (2014) for children with SLI and by Mollink, Hermans and Knoors (2008) for children with hearing impairments. One could therefore conclude that producing the gesture during training is not necessary for a positive effect of gesture on word learning to emerge. Note that in all the above-mentioned studies (except Capone & McGregor, 2005 and Mollink, Hermans, & Knoors, 2008), the positive effect was only observed for receptive (and not expressive) learning. The results of studies in which the participants were explicitly asked to or were allowed to imitate the gestures (Bird et al., 2000; de Nooijer et al., 2014; Kapalková, Polišenská, & Süssová, 2016; van Berkel-van Hoof et al., 2016) actually do not obtain better results in terms of expressive learning. McGregor and colleagues (2009) only found a positive effect of gesture after a two- to three-day delay. Even though the children did not imitate the gesture during training, they did enact the 'under' relationships learned on actual objects. This could have a similar effect as performing a gesture, which would explain the lack of a gesture advantage over word-alone training upon immediate testing: the children actually observed something close to a manual gesture even in the word only condition. The fact that a positive effect does emerge after delay could suggest that actual actions on objects even though positive for word learning are not as effective as manual gestures.

Some interesting observations come from studies in which imitation was not forced and which analyzed the correlation between imitation and word learning performances. In Bird et al. (2000), the participants were not required to, but could, imitate the gestures during training. Correlational analysis showed no correlation between imitation vs. none and word learning performance for children with T21 but did find moderate to high correlation for TD children. De Nooijer and colleagues (2014) tested receptive verb learning and included both a condition in which participants only observed the gesture and one in which they were also asked to imitate the gesture. They did not find any advantage of imitating the gesture rather than just seeing it.

It could also be the case that producing the gesture upon recall could facilitate the latter. Only one study directly controlled for gesture production during testing. O'Neill, Topolovec and Stern-Cavalcante (2002) found a positive correlation between descriptive gesture production during testing and receptive performance in TD children only for two out of the five adjectives learned in experiment 1 but for all adjectives in experiment 2. Kohl, Karlan and Heal (1979) also controlled for sign production during recall in children with disabilities but did not correlate that measure to word learning performance. The same can be said of Romski and Ruder (1984) for children with T21 and Capone (2007) for TD children. Mollink, Hermans and Knoors (2008) asked the hearing-impaired participants to repeat the word during training but no indication is given as to whether they imitated the signs.

An interesting study relevant to the present question is that of de Nooijer and colleagues (2013). It was not included in the review itself because it did not directly compare the use of gestures during learning with that of other cues. In their study, participants (N=120; mean age = 10 years) learned verbs always associated with a gesture during training. The focus was on analyzing the effect of gesture imitation (or not) by participant during learning and/or recall. The verbs were of three types: abstract, locomotion or object-manipulation. They found a positive effect of imitation (over none) only for the object-manipulation verbs. They suggest that gesture imitation would be crucial only when the action imitated is goal-directed.

Imitation of the spoken word also appears to be a crucial factor. Bird and colleagues (2000) indeed found significant correlations between spontaneous imitations of the word during learning and the expressive and receptive learning performances. There was no analysis of specific gestural imitations, which were infrequent in the TD participants.

The study by de Nooijer and colleagues (2014) included an extra interesting condition in which they asked the children to invent a gesture for the word. They found that the children invented gestures very similar to those the experimenters had invented for the other experimental conditions (sometimes simplified). However, no clear positive or negative effect of this condition over the others (no gesture or gesture from the experimenter) emerged.

In a nutshell, producing the manual gesture during training does not appear to be absolutely necessary since several studies find a gestural advantage even if the children only observed the gesture during training. A few, but not all, studies however showed a positive correlation between production of the manual gesture during training and better word learning performances. Results are still too sparse to draw a strong conclusion. One study also showed that producing the gesture during testing results in better word recall.

3.9. Analyzing generalization

Another interesting aspect of learning is generalization. Once the words are learned in one context, it is indeed important to be able to generalize their use to other contexts. Category generalization corresponds to the capacity to be able to use nouns labeling objects for other objects of the same category (for example, being able to use the noun for the same object in a different color than during training). For action verbs, generalization corresponds to the ability to use the verb to describe a similar action in another context (for example, being able to use the verb to describe the action but performed on different objects than during training). For adjectives, generalization is the ability to use the newly learned word to qualify a different object having the same property than that designated by the learned adjective.

Booth, McGregor and Rohlfing (2008) found that TD children managed to receptively generalize the use of new words to objects from the same category more when the words were trained with a pointing gesture. Capone Singleton (2012) obtained the same results for iconic gestures underlying shape, both receptively and expressively. McGregor and colleagues (2009) found the same but only receptively and only after a two- to three- day post-training delay. In the two latter studies, the participants learned nouns for objects in three conditions: with an iconic gesture depicting the object's shape, with one illustrating the object's function or with none. They were then tested on the generalization of the use of the noun for another object of the same category (similar shape and same function). They did this more efficiently when they had learned the noun with a shape gesture than with no gesture (not true for function gestures, see above for discussion on this potential shape bias).

O'Neill, Topolovec and Stern-Cavalcante (2002) found that descriptive gestures were more efficient then pointing to receptively generalize the use of adjectives to new objects by TD children. In Experiment 2, the adjectives described non-visible properties of the insides of objects and participants were asked to generalize the adjectives to objects of different shapes and colors but with the same non-visible property.

Romski and Ruder (1984) found that signs helped children with T21 receptively generalize the use of new verbs and nouns but impeded expressive generalization. Participants learned verb/noun combinations describing actions performed on objects and were then tested on how they generalized the use of the nouns and verbs when they were combined differently than during training.

Mumford and Kita (2014) compared the effect of adding manner or end-state gestures to verbs during learning with a control condition with no gesture. The participants were then tested receptively on their generalization performances. Children were taught a verb alongside a gesture focusing on the manner of the action or one focusing on the end-state or none. They were then asked to select from two videos which one corresponded to the verb label. The materials were different but one of the videos displayed the same manner as during training and the other one the same end-state. They found that participants generalized more often based on manner when they had seen a manner gesture during training (no preference bias for end-state gestures and no gestures). The authors draw several conclusions from their findings: 1. the fact that the results are different for manner and end-state gestures suggests that the "gestural content" plays a role; 2. the fact that children manage to generalize suggests that "gestures do not simply help children to associate a word with a scene in general"; 3. "iconic gestures provide a sketch of abstract semantic representations of verbs, which help children carry out fast mapping (…) of newly encountered verbs and correctly apply the verbs to novel complex scenes".

To summarize, several studies find that manual gestures play a positive role in generalizing the use of newly learned words to new contexts. McGregor and colleagues (2009) suggest that: "gesture input promoted more robust knowledge of the meaning of *under*, knowledge that was less tied to contextual familiarity and more prone to consolidation" (p. 824).

4. Summary and explanatory hypotheses for the role of manual gestures in word learning

This chapter reviewed a total of 19 articles describing 20 experimental studies examining the effect of using manual gestures during training on word learning. Even though this was not a criterion for selection, they all tested children of various ages who were either typically developing (TD) or with speech and language difficulties from various origins: hearing impairment (HI), specific language impairment (SLI), trisomy 21 (T21), cerebral palsy (CP). Based on these studies and their results, several research questions were addressed in order to try and better understand the potential role of gestures in word learning.

The first question (section 3.2.) was very general and asked whether manual gestures, whichever their type, actually improved word learning performances in TD children. Five out of eight studies involving a total of

212 children and directly comparing a word + gesture condition to a word only condition found better word learning performances in the word + gesture condition. Two studies, testing a total of 29 children, found no difference between conditions. The results of all the studies reviewed therefore suggest that supplementing a word with a manual gesture during training is beneficial to word learning (see section 3.2. for more details).

Section 3.3. examined the same research question in children with speech and language impairments. Six out of seven studies involving 74 children and directly comparing a word + gesture condition to a word only condition found better word learning performances in the word + gesture condition for at least one group of children with speech and language impairments. Two studies, testing a total of 25 children, found no difference between conditions. In these two latter studies, the children were not disadvantaged by manual gestures either. All this suggests that using manual gestures to teach new words to children with speech and language impairments could be useful. The studies reviewed indeed show that using gestures at worst does not have a positive effect and at the best promotes word learning, but in no cases impedes it. The evidence reviewed here actually suggests that children with speech and language impairments would benefit even more from manual gestures than TD children (see section 3.3. for more details). This could have implications for speech and language intervention.

Section 3.4. tackled the question of the specificity of gestures over other additional cues for word learning. The results of the studies comparing the use of manual gestures, be it pointing or iconic representational gestures, to other cues, such as pictures, all suggest that there is a specificity of manual gestures which promote word learning more than other additional cues.

Section 3.5. further examined the potentially different effects manual gestures could have on expressive vs. receptive learning. Expressive learning refers to the ability to produce the word when asked and receptive learning refers to the ability to comprehend the word after training. In general, performances in receptive learning are better than those in expressive learning. Receptive learning appears to be positively influenced by manual gestures as long as not too many words are taught. Expressive learning was shown to take longer than receptive learning and requires more training sessions. A manual gesture advantage thus only appears when a sufficient number of training sessions is used. Finally, the studies reviewed suggest that the positive effect of manual gestures on expressive word learning is greater for children with speech and language impairments even though it is also true that these studies generally used more training sessions than those involving TD children (see section 3.5. for details).

Section 3.6. aimed at analyzing whether different types of gestures had different effects. The studies reviewed suggest there are differences between manual gestures of different types in terms of effect on word learning. Pointing appears to be helpful for word learning even if the positive effect would be weaker than for iconic gestures. Even if the results do not all agree, iconics would be more beneficial than arbitrary signs even if the latter do also have a positive effect. It also appears that type of iconicity (e.g., underlining shape vs. function) would have differential effects even though this appears to interact with the type of words learned (e.g., nouns vs. verbs) (see section 3.6. for more details).

Section 3.7. tackled the question of testing time and the potential differences between gestural effects for immediate vs. delayed testing. In immediate testing, a positive effect of manual gesture most often appears only for receptive learning in TD children as well as in children with speech and language impairments. This beneficial effect generally holds in time and still can be observed upon delayed testing. The positive effect sometimes appears only after a certain delay (at least one night) especially for expressive learning (see section 3.7. for details).

Section 3.8. examined whether actually producing the gesture, vs. just observing it, during training yielded different results. The results of the studies reviewed suggest that gesture production during training is not mandatory for a beneficial effect of manual gestures to appear. Some results however suggest that producing the gesture during training would result in a greater positive effect of manual gestures. Production of the gesture during testing could also yield better recall performances (see section 3.8. for details).

Finally, section 3.9. analyzed potential effects of manual gestures on generalization performances. Some results suggest that manual gestures could enhance generalization of the newly learned words to other contexts.

In the following, we will address different hypotheses to explain why gestures would play a beneficial role in word learning based both on personal thoughts and on those proposed by other authors.

4.1. Do gestures simply function as attention attractors to the word learning context?

A hypothesis to explain why gestures facilitate word learning could be that using a gesture during training would function as an attention getter: the gesture would help focus the learner's attention on the object of the training, i.e. the word pronounced by the experimenter. Joint attention (Tomasello, Carpenter, & Liszkowski, 2007), which is important for learning, would be enhanced by the gesture. If this is the case, one could expect that gestures would not facilitate learning more than any other means of attracting attention. Some of the studies reviewed in this chapter provide information relative to this question.

Booth, McGregor and Rohlfing (2008) compared the use of pointing towards the labeled object and the use of gaze towards the latter. They found that learning performances are better in the pointing than in the gaze condition. They also controlled for child attention by analyzing looking time of the participants when the experimenter labeled the object during learning. They found that the participants' looking time towards the target object did not differ between conditions. This suggests that the level of attention was the same across conditions and that, even so, the use of pointing enhanced receptive word learning. The authors conclude that: "socio-pragmatic factors come to play a larger role than perceptual-attentional factors in word learning by the time the children reach 2 ½ years of age" (p. 198). This suggests that there is something more to manual gestures than just drawing attention to the word learning context. Note however that O'Neill, Topolovec and Stern-Cavalcante (2002) found a percentage of correct responses in the pointing condition very close to chance suggesting that learning did not occur in the pointing gesture condition whereas it did in the descriptive gesture condition in Experiment 1. Performances were however higher than chance in the pointing condition in Experiment 2.

Bird and colleagues (2000) did not find better expressive and receptive word learning performances when words were associated with an arbitrary gesture than when they were associated with no gesture. If gestures solely functioned as attention getters, arbitrary gestures should also attract the participants' attention.

Kapalková, Polišenská and Süssová (2016) found that providing a manual iconic gesture during training yielded better expressive learning performances compared to providing a picture. McGregor and colleagues (2009) also found that an iconic gesture was more efficient than a photograph for learning the meaning of the preposition 'under'. It however seems that gesture and picture/ photographs should equally function as attention getters. Capone Singleton (2012) compared the effect of shape gestures, function gestures and pointing gestures and found that shape gestures yielded better expressive learning and category generalization performances than function and pointing gestures. Even if one could argue that a representational gesture could function as a stronger attention getter than a pointing gesture, there is no reason why a representational gesture underlining shape would focus attention more than one underlying function. The authors suggest that "Whereas both pointing and iconic gestures can draw attention to an abject, the iconic gesture may also orient children to attend to or strengthen their inferences about specific features and their connection to the word label" (p. 289–290).

Vogt and Kauschke (2017a) found a positive effect of iconic gestures over an attention directing gesture (raised forefinger in front of upper body) both for fast and slow mapping expressive and receptive learning of new words by children with SLI as well as age-matched and language-matched TD children: "iconic gestures provide an advantage over and above focusing children's attention" (p. 21). Note that receptive and expressive learning also occurred in the attention-directing gesture condition even though to a lesser extent than in the iconic gesture condition. The advantage of iconics vs. the attention-directing gesture further depended on testing time and word type: it was only significant for verbs for fast mapping and for nouns for slow mapping.

Put together, all this evidence suggests that either gestures have an additional role than just attracting the learner's attention, even more so for iconic representational gestures, or that gestures attract attention more than other cues as hypothesized by McGregor and colleagues (2009): "gestures are interesting, and thus draw more attention to moments of training" (p. 822).

4.2. Memory enhancement

Manual gestures could function as additional traces to help the learner memorize the new words more efficiently. Several of the studies reviewed in this chapter provide insight on this hypothesis. McGregor and colleagues (2009) put forward a gestural advantage only after two- to three-days and not immediately. Lüke and Ritterfeld (2014) also found a gestural advantage only after a one-week delay and not immediately for expressive learning. Finally van Berkel-van Hoof and colleagues (2016) found that the gestural advantage grew over time. All this evidence suggests that gestures help learners memorize new words longer than when the words are trained without a gesture.

Mollink, Hermans and Knoors (2008) compared word learning performances after one and five weeks. They found a gestural advantage but no differential effect between strong and weak iconicity signs after one week. After five weeks, performance decreased but only for weak iconicity gestures and not for strong iconicity ones. This suggests that iconicity favors longer memorization.

Studies on word and sentence list recall also provide information on the question. In these studies, participants are generally provided with a list of words or sentences that they are instructed to try to memorize. Cohen and Otterbein (1992) showed that pantomimic and non-pantomimic gestures both favored the recall of sentence lists when these did not form a narrative. Feyereisen (2006) found a similar result for representationals and non-representationals and Thompson (1995) for iconics. Igualada, Esteve-Gibert and Prieto (2017) showed that three-to five-year-old children recalled words better when these were presented with beat gestures than when they were presented alone. All these studies suggest that when manual gestures are present during encoding of the memory, it is better encoded. The same phenomenon could be at work for word learning.

4.3. Cognitive load minimization

Manual gestures may also minimize the cognitive load involved in word learning as suggested by Goldin-Meadow and colleagues (2001). This study did not directly tackle word learning. Participants first viewed a sequence of letters they were asked to memorize, they then had to solve a math problem after what they were asked to recall the sequence of letters. Those who could gesture during math problem solving recalled more letters than those who were prevented from gesturing. The authors suggest that gesturing lessened cognitive load during problem solving freeing space for memorizing the sequence of letters. McGregor and colleagues (2009) suggest that gesture "externalized a meaningful aspect of the referent in the visual world. By making that meaning more obvious, gesture may free cognitive-linguistic resources for processing the word itself and, perhaps the other lexical and syntactic elements involved" (p. 823). Gestures could help reinforce the link between the lexical form and the concept it refers to by putting forward a distinctive property of the meaning the word refers to, depicting it and attracting the learner's attention to it. Illustrating this link could free part of the cognitive load involved in finding this property and processing this link. This could free more cognitive load to actually learn the lexical form associated with it.

5. Conclusion

This review of experimental evidence of the role of manual gestures for word learning shows that even if there is not a gestural advantage in all studies, the majority of them show that words are learned more efficiently when they are associated with a manual gesture during training in typically developing children. This effect appears to be even stronger in children with speech and language impairments. Manual gestures are more efficient than other additional cues such as pictures. Even if manual gestures appear to play a positive role for both expressive and receptive word learning, receptive learning is faster. The gestural advantage seems to be present for different types of manual gestures, it appears to be strongest for gestures bearing a physical resemblance with the referent. Some studies find a gestural advantage even immediately after training while others find this advantage only after a delay.

The evidence suggests that manual gestures play a deeper role than just attracting the learner's attention. Gestures could facilitate word learning by enhancing memorization and/or alleviating cognitive load.

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