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Ursula Bellugi is one of the prominent researchers in the psychology of language. She currently serves as the director of cognitive neuroscience at the Salk Institute for Biological Studies. This paper will examine three areas of Bellugi's work from the last five decades. In the 1960s and 70s she compared the sign language acquired by Washoe the chimpanzee to human language. In the 80s and 90s her studies of deaf and non-deaf users of American Sign Language led to the conclusion that the left hemisphere is the center of all language processing. And in the last twenty years, Bellugi has supervised experiments of individuals with Williams Syndrome, a cognitive disorder that impacts intelligence and visuo-spatial skills, but not language.

Washoe the Chimpanzee

In 1970, Bellugi co-authored a paper with J. Bronowski analyzing the linguistic development of Washoe the chimpanzee compared to that of a human child (1). Beginning in 1966, Allen and Beatrix Gardner raised a chimpanzee named Washoe and used sign language around her, but did not explicitly teach her to sign (2). Within two years Washoe had acquired and made use of hundreds of signs. Bellugi and Bronowski analyzed the Gardners' diaries in an attempt to find an evolutionary link between the sign language acquired by Washoe between one and three years of age and the language used by humans at the same age (1).

While Washoe was able to develop a substantial vocabulary of signs, she never reached the complexity of human language. Like a human child, Washoe's communication focused on the present moment as shown by her ability to name objects in the environment around her. She could never communicate greater concepts, however. By three years old, a human child can talk about things in the recent past or in the near future, will have developed sentence structure, and asks and answers questions with ease. Washoe failed to attain these landmarks in the development of language. Bellugi and Bronowski concluded that the evolution of human language relied more on the existence of the mind than on the ability to communicate.

American Sign Language

Bellugi was a key researcher in the understanding that the left hemisphere controls all aspects of language. Her experiments from the 1980s and 1990s used both deaf and non-deaf test

subjects fluent in American Sign Language (ASL). The results showed that no matter the type of communication, verbal or signed, the left hemisphere was responsible for interpreting the linguistic input.

The first part of Bellugi's research was with deaf people who had damage in one hemisphere of the cortex caused by a stroke (3, 4). If the lesion occurred in the left hemisphere, the patients had difficulty signing, but if the lesion was in the right hemisphere, visuo-spatial skills were impacted but signing was not. This meant that the left hemisphere interprets not just auditory information, but also signed language.

Bellugi then expanded on this conclusion in more sophisticated studies. In one experiment, she asked a group of non-deaf, right-handed, native signers to tap a telegraph key connected to a computer that recorded the number of taps per minute (5). First a baseline tapping rate was established. In the first trial, subjects were shown a video of one signed word per second and in the second trial they listened to a recording of one spoken word per second. While they watched or listened, they continually tapped with their right index finger. This was then repeated with tapping of the left index finger. The difference in rate of tapping between each trial and the baseline was calculated. The rate of tapping dropped when the subjects were using their right hand, but was equal to the baseline when using the left hand. This meant that the left hemisphere was busy interpreting the signs and words, causing the right hand to slow down. It also showed that the right hemisphere does not process either spoken or signed language, causing the left hand to tap unimpeded.

Using the same setup, Bellugi did another experiment instead with a group of deaf, right-handed, native signers (5). They were shown video clips of ASL signs, meaningful gestures (for example a wave hello or a thumbs up), and non-meaningful gestures (complex movements with no significant connotation). Right hand tapping decreased significantly when the subjects saw signs. In all other cases, the tapping rate matched the baseline. Again, Bellugi had solid experimental evidence that the left hemisphere is active during tests of language, and was able to prove that the ASL signs were distinct to the left hemisphere from other movements.

Williams Syndrome (WS)

During the last fifteen years, Bellugi has been the leader in research on WS. WS is a neurodevelopmental disorder that causes moderate intellectual impairment, especially in visuo-spatial processing, yet patients have high linguistic skill in addition to their high level of

sociability (6). People with WS have elfin fanes and are drawn to social situations where they can interact with others (7).

The social aspects of WS are somewhat contradictory. People with WS lack social inhibition – they will talk to anybody, even strangers, regardless of appearance or negative social cues (8). This is the cause of their trademark extroversion. Despite their love of social situations, those affected by WS have a hard time making and keeping friends (6). No explanation for this has been found yet. Our understanding of WS is limited still, but Bellugi and her colleagues are working to change that.

Bellugi was featured in an episode of PBS's *Scientific American Frontiers* to demonstrate some of the experiments used by her team to study WS. For example, a researcher creates a shape with blocks and asks the patient to replicate the shape with his own set of blocks, which he is unable to do. In another case, the researcher asks a series of questions with numerical answers such as, "what is the annual salary of a doctor?" and "how much does a new car cost?" The patient's answers are wildly off: he thinks the doctor makes about 12 dollars per hour and the car costs 10,000 dollars. These tests show the visuo-spatial and intellectual limitations that cause WS.

In a different test, the patients are shown pictures of faces and have to press a button when they see faces that match (7). During the test an electroencephalograph (EEG) measures electrical activity in the brain. A normal person shows activity only in the right hemisphere during the test, while someone with WS shows five times as much activity throughout the entire cortex. This demonstrates the stimulation that social situations provide for people with WS and explains why they are so drawn to interacting with others.

The high linguistic skill of WS patients is related to their fondness of social situations. In one experiment by Bellugi and her team, they asked children to read an illustrated story without words aloud to others (6). The children with WS made more grammatical errors than the control group, but they used more rhetorical devices that helped keep the reader's interest such as use of sound effects, various voices, and word intensifiers. For example, typically developing children simply called a frog a frog, but WS children said "froggie froggie" and "froooooog." Such techniques helped the WS children keep their readers engaged, facilitating a social interaction rather than a monologue.

Another unique characteristic of WS is exceptional musical talent (9). Bellugi and her team discovered a structural anomaly in the brains of people with WS related to their musical abilities. Using magnetic resonance imaging (MRI), they found that the planum temporale region in WS patients had asymmetry comparable to that of musicians and significantly different from that of a non-musician control group. At the time of publication in 1995, the research team had yet to determine if the asymmetry directly caused increased musical talent. Bellugi suggested that perhaps the asymmetry could have an impact on the linguistic skills of people with WS instead.

A genetic basis for WS has been confirmed. The cause is a deletion on one copy of chromosome seven of about 25 genes (7). Bellugi explains that this makes WS a great case for studying the relationship between genes and the brain. Bellugi even believes that one day we may be able to identify a gene for sociability based on the work already done by her research team.

Conclusion

Ursula Bellugi has become prominent in the field of neuroscience over the course of her career. Her work on the neurological system behind language cemented our understanding that the left hemisphere controls processing of language thanks to her studies of American Sign Language. By undertaking a variety of research methods (analysis and experiment of chimpanzees, deaf humans, and people affected by WS) she has made progress in the field and established herself as an important researcher.

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